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Cladophora As Related To Pollution and Eutrophication in Western Lake Erie

By
Clarence E. Taft
W. Jack Kishler

United States Department
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State of Ohio
Water Resources Center
Ohio State University

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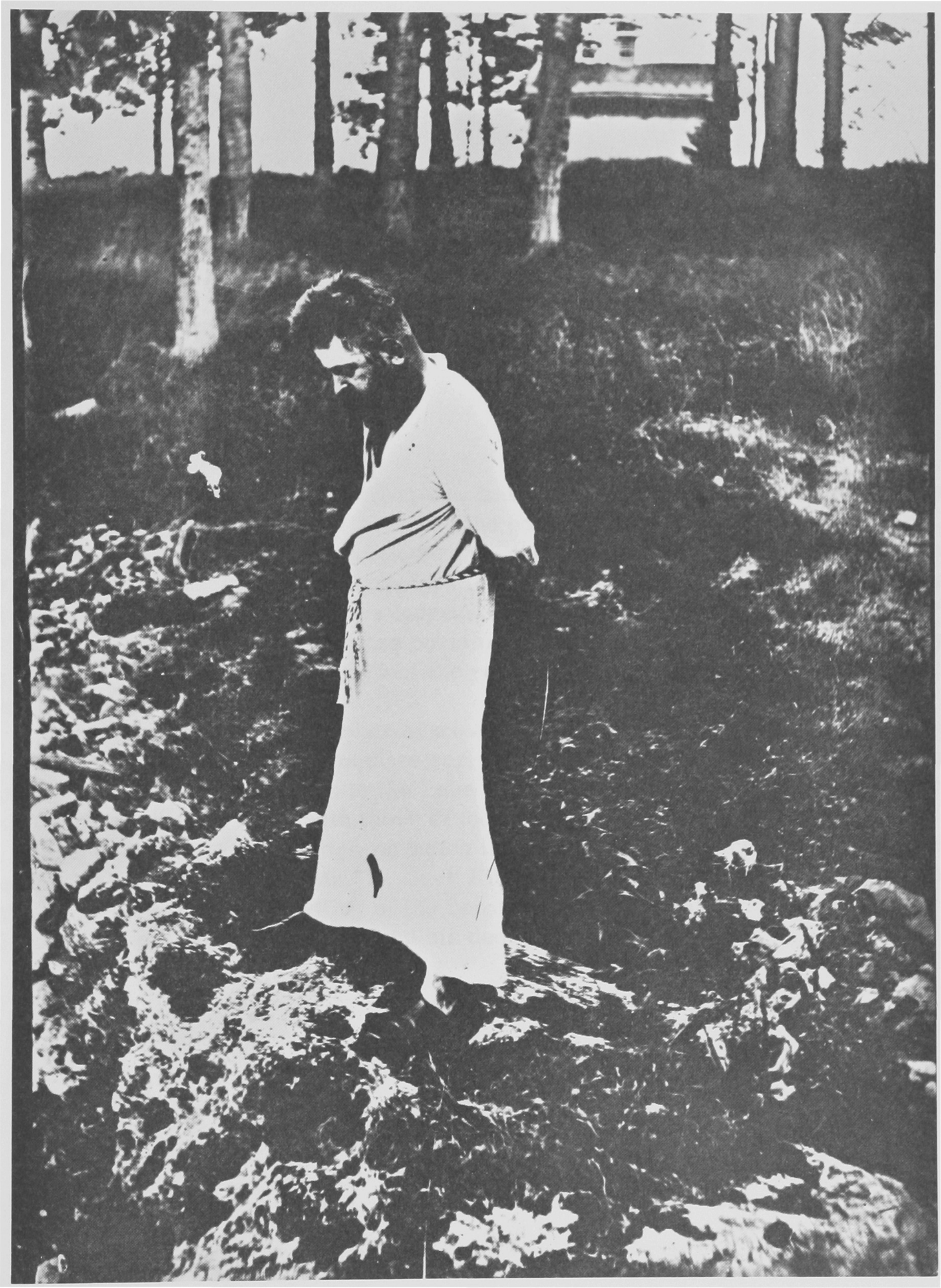

Mendicant meditating on 19th. Century Cladophora beach drift, Gibraltar Island, Put-in-Bay, Ohio.
Photograph from the J. Cooke Collection. Courtesy of the Ohio Historical Society Library, Columbus, Ohio.

FOREWORD

The study covered by this report was initiated because of the wide distribution of Cladophora in western Lake Erie and the possible association it might have with pollution and eutrophication. Little beyond occasional observations has been known about the part this ubiquitous alga plays in the ecosystem. Some believe it to be a relative new-comer that portends increased pollution in the basin, or that it is by itself a prime pollutant. Some are certain that Cladophora in the Lake is directly related to pollution while others feel the relationship is not as clearly understood as some would like to believe.

The Report provides a number of excerpts from early historical records that concern the Lake and the immediate surroundings. These permit the reader to more readily understand conditions in the Lake as they were one hundred or more years ago and to compare them with those of today.

The necessary field studies on which this report is based are largely the work of the junior investigator, Mr. W. Jack Kishler. He should also be credited with the major portion of the writing of the report. The principal investigator acknowledges with gratitude his efforts and his dedication to the Report.

ACKNOWLEDGEMENTS

Generous accomodations for this Project were provided at the Ohio State University Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, by the Director, Dr. Loren S. Putnam.

Hundreds of public agencies are not only efficient vehicles for carrying out our most expressed desires for the Lake, but have been found to be unstinting desseminators of information to whom it may concern. The writers are most grateful for the aid extended by these agencies and for that by numerous individuals who have cooperated.

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INTRODUCTION

Witness the tract of earth - the western basin of Lake Erie - that has had several hundred times the productivity of the regional - Great Lakes - average, as weighed during the tract's declining decades. Originally, some of the world's finest protein food was harvested along with abundant, high-quality water and resiliency for hardened people. Now, excessive cultivation of the surrounding land has shifted the yield to weeds. (Protoplasmic units not easily rendered into dollars.) National wrath is called on the tract because it is not purely barren. The possible solution could be in the piping of clean water into Lake Erie, and the return of the accumulated sludge back to the land.

The people around Lake Erie do not lack superlative guidance on their aquatic environment. A recently televised hour-long documentary on Lake Erie, according to viewers, contained filmage from Lake Michigan and the Rhone River, France. Will this happen with our other lakes and rivers? A poll taken in the southern part of the Maumee watershed would reveal that many people there do not know they are in the Maumee watershed. Cities in that watershed charge the air with hydrogen ions, many of which wash out and replace untold soil nutriments, which are then released to Erie waterways. Other cities, according to critics, have a better idea -- grab everything possible from the environment and stagnate a Great Lake. Industrial giants from all sides privately decide most water usage. In the Washington arena, Youngstown and Pittsburgh interests pushed for a navigation canal from the Ohio River to Lake Erie; the Port Authority of New York City was instrumental in delaying the project. The east coast feels a Niagara power shortage squeeze and Great Lake steamship companies want higher profit ceilings through deeper harbors -- then authorities in control announce plans to maintain high water levels. The highest government center within the Erie watershed is the county seat. The watershed is fractured with absolute disregard for the ecosystem amongst a Province and five states and ditching projects are automatically authorized by self-perpetuating agencies.

The Environmental Protection Agency (E.P.A.) can live with any amount of mud if it is low calorie. Public plans affecting Lake Erie are drawn mostly by administrators in areas contiguous to the Lake, but they have been known to originate as far away as Texas. An incoming Ohio Governor reputedly once ordered the disposal of resource records over several years old. Soon after the 1953 lake bottom and mayfly disaster, one of the world's finest aquatic biology research laboratories was told, to a round of public "ho hums", it would no longer be a waste of the Ohio State University money in Lake Erie, but rather was permitted survival as a summer school. Since then there has been an excessively popular crusade to save Lake Erie by starving it. However, efforts to control the central factor of mud in the watershed remain diffuse: the problem does not lend itself well to a scapegoat type of solution.

It would seem to border on treason for people to halt our march of hostility on the aquatic environment. We know what happens to Indians who step out of line. Instead, we are to pump blood into the cities faster, so they can finish wearing out the landscape, so we can buy a new one? Risking motivation in this, an attempt is made to describe the old landscape through the eyes of early viewers of European descent.

HISTORICAL QUOTES CONCERNING WESTERN LAKE ERIE

As a prelude to the quotes and by the middle of the 1600's, the people of the infant town of New York had become anxiety ridden about missing out on a bonanza. Beavers were quite the rage of Paris, and North American invaders were on a beaver standard of currency. The Hurons, who had traded for beaver with various Algonquins, mainly the Ottawas, were funneling the trade through Montreal. The region of upstate New York was the corner of Huron country where they had chased their trifling outcasts. These maligned people, called Iroquois, agreed with New Yorkers that the Hudson River was a better funnel for beaver trade, and they were admitted to the fraternal order of the arms race. By the time they got around to the more numerous Eries, they were taken seriously enough that the entire Erie nation burned all their own villages and withdrew to a common musket shelter for a showdown. No American invader had ever claimed to have seen an Erie: they were cleaned out, perfectly. For one century, the Iroquois were said to have created a solitude around Lake Erie and called it peace. This may be considered the first lesson from the east to those who viewed the Lake Erie region as a source of their stimulation, rather than as the regimented source-dump for their extended products. However, they never got through to the Ottawas.

The following excerpts from a multitude of sources over many intervening years provide a glimpse of the historical aspects that contributed to Lake Erie, past and present, and of some of the contributing factors from its contiguous environs.

Summer, 1688. Baron de Lahontan ("he anticipated Rousseau, foreshadowed Voltaire"). Edited by Thwaites, R. G. (1905).

"Lake Erie assuredly 'tis the finest Lake upon Earth. It might be made the finest, the richest, and the most fertile Kingdom in the world." (and he beat today's purists to the punch by 2.84 centuries)

4 May 1804. Hopkins, Gerald T. (1862)

Becalmed at Middle Bass Island. "The small boat was rowed around the islands, whilst we cast our lines, about thirty feet in length, having the hooks baited with the skin of pork and covered in part with a piece of red cloth. In a short time we caught upwards of five dozen black bass - weighing from four to six pounds. The lake water is so clear that fish can be seen from twelve to fifteen feet below the surface. Many of the fish we caught we saw advancing to our hooks."

The winds on the previous day were "light" and the day before that "unfavorable", detaining them at Malden. The remainder of that week Hopkins spent mostly indoors at Detroit and did not comment on the weather. The previous week was one of "high winds and heavy rains" along the west shore of Lake Erie.

1827-28. Hall, Capt. B. (1829)

"Lake Erie, the colour of whose waters was green not blue like those of Lake Ontario."

9 May 1804. Hopkins, G. T. (1862)

"Lake Erie is a very beautiful body of water . . . the water of the lake appears to be of a beautiful deep green color, but when taken up in a glass vessel is to be admired for its transparency. I think it is without exception, the sweetest water I ever drank."

June, 1850. Cabot, J. E. in Agassiz (1850)

"The (Niagara) is of such a dark and solid green, that it is difficult to persuade one's self that it is not occasioned by some colored matter suspended in the water. It bends over in a polished unbroken mass, as if green glass over white. . . (First day underway on Lake Erie) - the water green, but less so than at Niagara . . . The water over these (St. Clair) flats is still as green as that of Lake Erie, and not more turbid . . . (Lake Huron) the water darker than Lake Erie."

1842. Drake, Daniel (1854)

"The shallow lakes Erie and St. Clair, are less transparent than the deeper ones above; for the wind agitates them to the bottom, which throws up a portion of its slime."

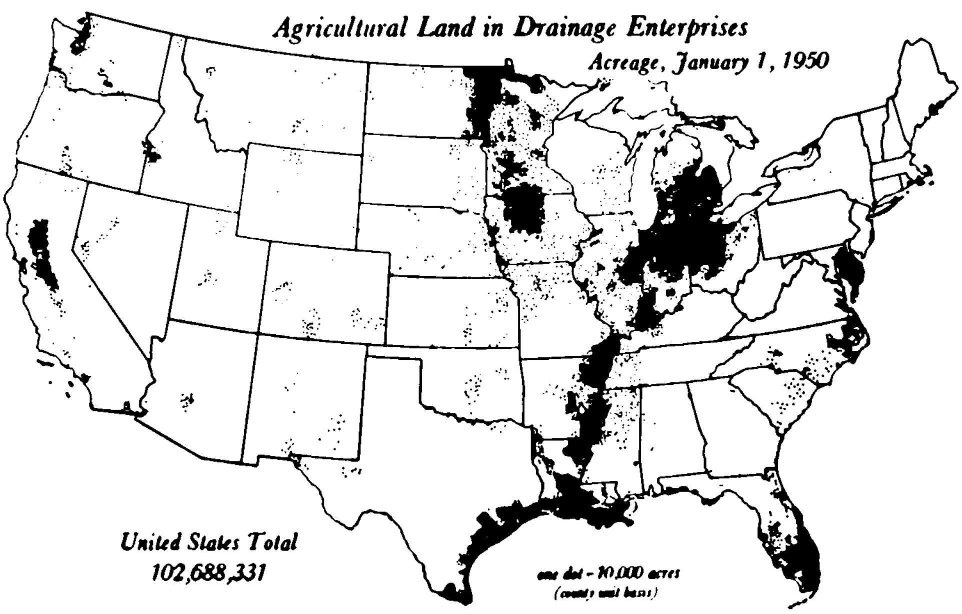
Blackwell, Thomas Evans (1866)

"A moderate gale of wind soon raises a sea in this shallow lake (St. Clair), causes the whole to become turbid, and tends thus to distribute the detrital matter, and convey it through the Detroit straits into Lake Erie, where similar accumulations, on a larger scale occur. Here, too, an ordinary storm raises a very heavy and somewhat dangerous sea, and soon disturbs the bottom, and favors the distribution of natural deposits which settle in calmer weather in the upper portion of this shallow basin."

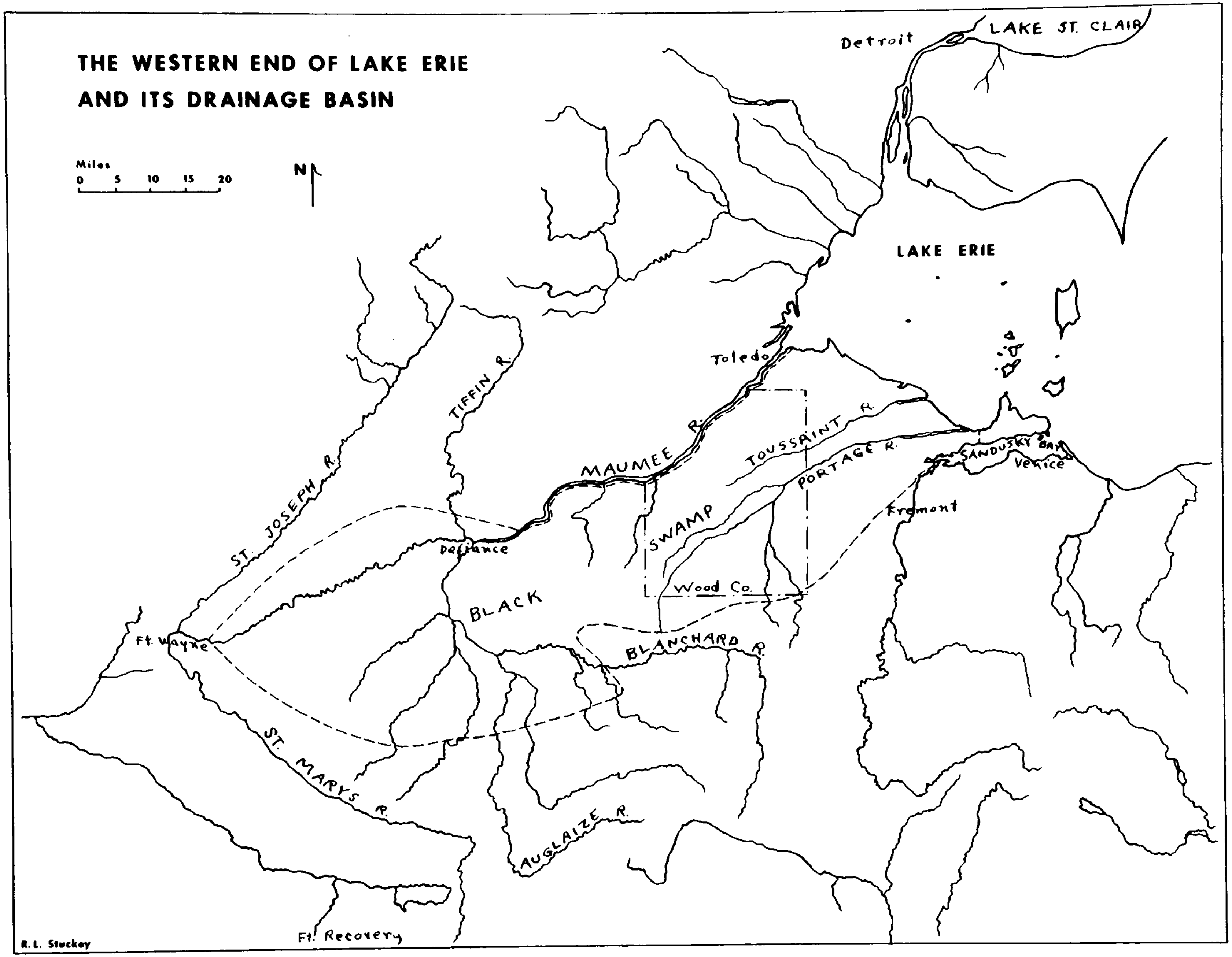
13 September 1865. Detroit Tribune

"(Lake St. Clair's) bottom being so muddy and yielding that in less than two years a sunken vessel will disappear altogether in the mud."

Figure 1. Agricultural land in the United States improved by drainage.



Photograph from the United States Yearbook of Agriculture, 1955.


THE WESTERN END OF LAKE ERIE
AND ITS DRAINAGE BASIN
Miles
0 5 10 15 20
N
Detroit
LAKE ST. CLAIR
LAKE ERIE
Toledo
TIFFIN R.
ST. JOSEPH R.
MAUMEE R.
TOUSSAINT R.
PORTAGE R.
SANDUSKY BAY
Venice
Fremont
SWAMP
Defiance
Wood Co.
BLACK
BLANCHARD R.
Ft. Wayne
ST. MARYS R.
AUGLAIZE R.
Ft. Recovery
R. L. Stuckey

Howison, John (1822)

"Beach (Lake Erie) being strewed with dead fish and shells."

1758. Pouchot, M. (1866)

"Head of Lake (Erie) storms arise very suddenly, and the waves are so bad, that in rough weather they often kill the fish which are found scattered along the shore."

9-13 October 1820. Flint, James, in Goldthwait, R. G. (1904)

"(Venice) has now only one family in it . . . (Sandusky) bay produces grasses and confervae (filamentous algae) that are washed ashore in times of wind, and emit disagreeable effluvia."

Bigsby, J. J. (1828)

"In a gale (Lake Erie) is rendered turbid by the sand and mud washed from the bottom. The water is always good some distance into the lake; but in summer near shore, it is much contaminated with animal and vegetable matters in a state of putrefaction. In that season in the middle of the day, the shoal water is heated to 90-95^{0}F."

1755-59. Smith, James (1870)

"Some of the Wyandots, or Ottawas, frequently make their winter hunt on these islands; though, excepting with fowl and fish, there is scarcely any game here but raccoons, which are amazingly plenty, and exceedingly large and fat, as they feed upon the wild rice, which grows in abundance in wet places round these islands. It is said that each hunter, in one winter, will catch one thousand raccoons."

1762. Carver, Captain Jonathan (1789)

"The lake is covered near the banks of the islands with the large pondlily; the leaves of which lie on the surface of the water so thick, as to cover it entirely for acres together, and on each day, when I passed over it, wreaths of water-snakes basking in the sun, which amounted to myriads."

1813. Brown, Samuel R. (1815)

"The Great Meadow (bordering the lake from Catawba to the Detroit River) cannot contain less than 200,000 acres . . traces of Indian corn hills are frequently met with."

"Tous Saints. It is impossible for me to give the reader a perfect idea of the difficulties and fatigue we experienced in getting to the grove. The grass was so thick that it would easily sustain one's hat - in some places a cat could have walked on its surface; in many places it was effectually matted by vines that required one's whole strength to break it down . . . The margin of the coast is several feet higher than the plain in its rear the whole length of the meadow. Its summit is covered with a row of trees. The mound was evidently formed of sand, shells and pebbles which the violence of the surf has been accumulating for ages; if it were not for this defense, the lake would often innundate the immensely valuable meadow."

Smith, Mich. (1814)

"The Grand River [Ontario] is a considerable large stream of exceeding clear water."

13 July. Hall, Francis (1818)

"The Grand River [Ontario] drifted slowly past, black and sluggish, as if it had been a stream of dark-coloured oil rather than water, this tinge being imparted to it, the inhabitants inform us, by Cranborough and Wainfleet marshes, of which extensive swamps it is the principal drain."

1761. Johnson, Sir William in Thwaites, R.G. (1904)

Conneaut Creek Harbor? "Water of a very brown color."

18 October 1811. Melish, John (1812)

At Cleveland, where there were "16 dwelling houses . . . The river being stagnant and contaminated by decaying vegetables afflicts the inhabitants on its margin with fever and ague. I am of the opinion that it must be contaminated with putrid animal substances when we visited it, for the smell was almost insufferable."

26 June 1834 Maximilian, Prince in Thwaites (1906)

"The dark brown waters of the Cuyahoga are strongly contrasted to a considerable distance with those of the lake."

1813. Brown, Samuel R. (1815)

"Follie avoine [wild rice] grows in about 7 feet of water, the stalks near the roots are about an inch in diameter, and grow to a height of 10 feet . . . Its yield is very abundant, being half a pint, at least, from every stalk. This valuable aquatic grain is found at the mouths of all the rivers which fall into the lake west of Sandusky, as far as (the Detroit River)."

1848. Drake, Daniel (1850)

On a voyage up Sandusky Bay and River: "After passing the gypsum quarries, the deep water becomes much narrower, and the color appears, first, a dirty yellowish green, and at last of a brownish hue. On each side of the channel there are extensive shallows from which grasses, pond lilies, and other aquatic plants rise into green savannas, animated with white cranes wading in the shallow water, and flocks of purple grackle."

6 February 1806. Carpenter, Helen M. (1935)

"In the agreement the Connecticut Land Company conceded (to the Sufferer's Land Company) that the waters of Sandusky Bay should not be reckoned as land."

However the Harbors remained reckoned as land.

1813. Brown, Samuel R. (1815)

"Portage-deep languid stream. Indeed the philosophic mind will rarely enjoy a richer feast than nature here presents him."

Sabrevois de Bleury, Jacques (1718)

The Maumee River's entrance "from Lake Erie is very wide, and on both sides, for a distance of ten leagues in ascending, there is nothing but continuous marshes. In these there is at all seasons game without end, especially in autumn and in spring; so that one cannot sleep on account of the noise made by the cries of swans, bustards, geese, duck, cranes, and other birds. Thirty leagues up is a place called la glaise (Defiance) where one always finds wild cattle (buffalo), who eat the clay and roll in it."

1756. Smith, James (1870)

At Little Cedar Point, Maumee Bay, "The river in this place is about a mile broad, and as it and the lake forms a kind of neck, which terminates in a point."

1813. Brown, Samuel R. (1815)

"Maumee Bay - Several thousand acres of follie avoine."

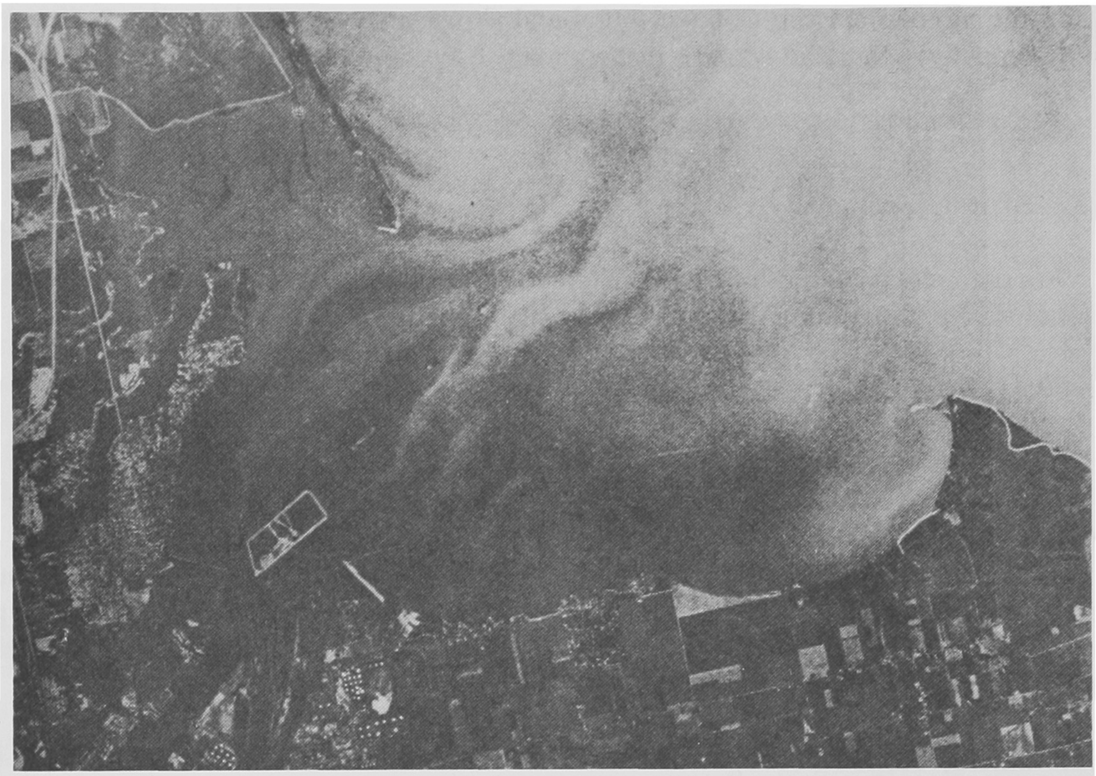
1848. Drake, Daniel (1850)

"Maumee Bay - almost separated from (Lake Erie) by two low and tapering capes. On the southern side of the bay there are grassy flats, so depressed that the waters of the lake, when driven by winds, flow over them. On the northern side, there are similar tracts, a continuation of the green margin which extends around the head of the lake, from the mouth of the Detroit River."

1859. Fahnestock, Aug. A., Horticulturalist in Waggoner (1888)

Comments on the "green scum" of the Maumee.

Figure 3. Aerial photograph of Maumee Bay showing pattern of discharges at mouth of Maumee River.



Photograph courtesy of Toledo Blade, Toledo, Ohio

"First, that it is the pollen or fecundating of an aquatic plant, the Zizaniae Aquatical, or Indian Rice. This plant is always found in low swampy land and along the borders of Rivers and streams. It attains an altitude of from three to nine feet, and begins shedding its pollen about the 1st of August and continues until late in September . . . From the immense quantities of this pollen, many would think it impossible to be of vegetable origin."

1813. Brown, Samuel R. (1815)

"River aux Cignes the pond lily, follie avoine, and other aquatic plants almost choke up the channel of the river, giving the water an offensive and putrid smell; it will rope like molasses. This is by far the worse looking stream tributary to Lake Erie."

Ecores and Rouge Rivers. "Many hundred acres of follie avoine."

1762. Carver, Captain Johnathan (1789)

"In the month of July it rained on (Detroit) a sulfurous water of the color and consistence of ink; some of which being collected into bottles and wrote with."

1813. Brown, (1815)

"The country around Detroit is very much cleared. The inhabitants have to draw their wood a mile and a half in the rear of the town. The street - from Lake St. Clair to River Rouge. A number of stores know how to extort an exorbitant price for everything sold. (Indians) whooping and shouting in the streets, the whole night. Women and children searching about ground for bones and rinds of pork, which had been thrown away by soldiers, meat in a high state of putrification which had been thrown into the river, was carefully picked up and devoured."

1848. Drake, Daniel (1850)

Black River, Michigan of the St. Clair River.

"The sources of this river are in tamarack swamps. Its water, like that of many other streams having a similar origin, has the color of ink, liberally diluted."

9 March 1815. Duncan, Ennis in Knopf (1956)

"A great deal of ice (of a greenish color which the French call Black Ice) running down the River Detroit from Lake St. Clair, the ice said to come out of the swamps on Lake St. Clair."

1813. Brown, Samuel R. (1817)

"The whole Peninsula of upper Canada is a champaign country. The lake coast is settled to Pt. au Pelee 30 miles east of Malden. The country to the rear of the fort is settled to the distance of 20 miles. River Aux Connards; a deep, muddy and sluggish stream (and) Turkey river an inconsiderable stream but deep and muddy."

15 April 1804. Hopkins, Gerald T. (1862)

Travelled 30 miles down the Maumee River from Fort Wayne with Chief Little Turtle. "The sturgeon are now on their way from the lake to the headwaters of the St. Joseph's and St. Marys Rivers."

16 April

Travelled 50 miles and past Fort Defiance. "River covered with wildfowl, fish jumping up around us, and turkies flying . . . Great numbers of Indians are settled on the banks of the (Maumee River). Most of the wigwams are covered with rushes sewed together, which are procured from the Shores of Lake Erie."

17 April

"Fish are now passing up the rapids in great numbers, insomuch that the water smells strongly of them. They are taken very abundantly by the Canadians and Indians. The fisherman without seeing them strikes his barbed spear to the rocks, which often passed through several at a time, and frequently of different kinds. The muscanonje are taken here in great numbers; they are a fish from three to five feet in length."

1794. Lt. Boyer, Diary of General Wayne's Campaign in Slocum (1905)

"30 July, Camp Beaver Swamp, eleven miles in advance of Fort Recovery no water except in ponds, which nothing but excessive thirst would induce us to drink.

1 August

Camp St. Marys River (Fort Adams) . . . Proceeded twelve miles. Our encampment is on the largest and most beautiful prairie I ever beheld . . . the water plenty but very bad . . . I am told there is plenty of fish in it.

4 August

Camp thirty-one miles in advance of Fort Recovery . . . The land we marched through is rich and well timbered, but the water scarce and bad; obliged to dig holes in boggy places and let it settle.

5 August

Camp Forty-four miles in advance of Fort Recovery . . . the land and water as above described.

6 August

Camp fifty-six miles from Fort Recovery . . . through an exceeding fine country, but the water still bad.

8 August

Camp Grand Oglaize (Defiance) seventy-seven miles from Fort Recovery."

6 Sept. 1813 McAfee, R.B. in Knopf (1956)

"About 4 miles (down the Auglaize River from the mouth of the Little Auglaize River) at the mouth of a second branch on high ground (east side), up which branch about two hundred yards is a fine sulphur spring the water which runs from it of a bluish milky colour about thirty steps below which is another whose water is as black as Ink."

Sept. 1794. A Kentucky Volunteer in Knopf, Richard C. (1953)

Camp on the Auglaize River, 1-1/2 miles from its mouth. "The water clear and a rapid current."

Enroute from Fort Wayne to Fort Recovery. "Loose sight of the beautiful rive(r) St. Maries."

20 Feb. 1790. Hay, Henry in Quaife, M.M. (1955)

"About 3 o'clock this afternoon the ice floated down the River and the Run all in a body. I don't think I ever saw a grander sight, a number of Loggs and trees stumps of trees and came down upon it."

This was the first of three days of tree discharge mentioned at Fort Wayne during this flood.

March 1818. Evans, E. in Thwaites, R.G. (1904)

Trip from Fort Stevenson (Fremont) to Fort Meigs (on the Maumee River).

"The wading was continually deep . . . the ice . . . was continually breaking and letting the traveller into water from two to four feet in depth. The freshets great, the banks of the creeks overflown, and the whole country inundated."

Bigsby, J.J. (1828)

Figure 4. Sand Dune, Wood County, Ohio.

Photograph by Royal Shanks

"The steaming swamps (western Lake Erie) which are almost universal are full of putrifying substances, occasioning the bilious remittents there so prevalent."

1848. Drake, Daniel (1850)

Black Swamp. "While the roots of these gigantic trees, standing side by side in the compactest intercolumniation, retard the escape of the melting snows and the copious rains of spring, their overshadowing foilage completely shuts out the sun of summer and autumn. The forest of greater density and loftiness than is to be found elsewhere, perhaps in the Interior Valley of North America."

Hopkins (1862) measured tree diameters between Drake's home, Cincinnati, and the Black Swamp. Diameters were 4-10 feet at 8 feet high.

1764 Morris, Capt. Thomas in Thwaites (1904)

When he came out of the swamp to a prairie. "the whole scene seemed an elysium."

1813. Howe, Henry (1847)

"The Black Swamp Mutiny . . . company put in charge of the prisoners taken by Commodore Perry and Gen. Harrison and march them across the State to the Newport Station in Kentucky. The company consisted of 100 soldiers and the prisoners numbered 400. They wandered about in the swamp and became so scattered that on the morning of the third day he found himself with a guard of only 12 men, and one hundred prisoners."

1813. Brown, Samuel R. (1815)

Banks of Sandusky River. "Land everywhere is rich, and its fertility is enough to astonish people, who have not travelled westwardly beyond Genessee."

Spring 1808. Ludlow, Maxfield in Carpenter (1935)

Field Book in Record Book of the Sufferer's Land Company. "Sat a Post in Hell. I have traveled the woods for 7 years, but never before saw so hideous a place as this."

Summer 1818. Darby, William (1819)

On the peninsula side of Sandusky Bay. "on no land of whatever quality did I ever before see so much black walnut on a given space."

At Sandusky. "Soil exuberantly fertile."

April 1756. Smith, James (1870)

A Wyandot, Tontileaugo, and his captive brother, James Smith, saw three horses "in exceedingly good order" by the Canesadooharie River, east of Sandusky. Tontileaugo decided they must run them down. Smith complained that they couldn't and that despite his reputation as a runner he was used to running only 8 miles at a time. But Tontileaugo had run down bear, buffalo, elk and deer and thought in a whole day he could tire everything but a wolf.

"In the morning early we left camp, and about sunrise we started after them, stripped naked excepting breech clouts and moccasins. About 10 o'clock I lost sight of both Tontileaugo and the horses and did not see them again until about 3 o'clock in the afternoon. As the horses run all day in about three or four miles square, at length they passed where I was, and I fell in close after them. As I then had a long rest, I endeavored to keep ahead of Tontileaugo, and after some time I could hear him after me calling chakoh, chakoanavo, which signifies, pull away or do your best. We pursued on, and after some time Tontileaugo passed me, and about an hour before sundown we despaired of catching these horses, and returned to camp, where we had left our clothes."

"I reminded Tontileaugo of what I had told him; he replied he did not know what horses could do. They are wonderful strong to run, but withal we made them very tired."

However, the forest brooder wasn't entirely hopeless by our standards. He so wanted a horse that the next morning he resorted to his technology to capture one.

27 August 1817. Stickney, Benjamin F., in Waggoner (1888)

Maumee Agent and major land holder, from a letter to Thomas L. M'Kinney, Superintendent of Indian Affairs, Washington.

"The civilization of the Indians is not a new subject to me . . . What I had viewed at a distance as flying clouds, proved upon my nearer approach to be impassible mountains . . . something of my ideas of the nature and extent of the obstacles to be met.

The insatiable thirst for intoxicating liquors that appears to be born with all the yellow-skin inhabitants of America; and the thirst for gain of some of the citizens of the United States.

General indolence, connected with a firm conviction that the life of a civilized man is that of slavery, and that savage life is manhood, ease, and independence.

The unfavorable light in which they view the character of the citizens of the United States -- believing that their minds are so occupied in trade and speculation, that they never act from any other motive."

1824. Gage, James Lee, in The Firelands Pioneer (1865)

"There were on the lower Maumee quite a number of mongrel French and Indians; and in the fourteen counties (now nineteen counties of northwestern Ohio) there were more savages than white people."

1832. Scott, V. W. in Van Tassell (1929)

"The Indian trade, in furs and the fisheries, with corn growing on the bottom lands, constituted the business on which these hamlets relied for support; and with few exceptions, the inhabitants failed to anticipate any considerable change from that condition. There were probably living, within the limits (of Toledo) about 2,000 people -- many of them holding on with a view to the business that was expected to flow in on the completion of the Wabash and Erie and the Miami and Erie Canals, then being constructed."

Slocum, Charles E. (1905)

"In 1834-5-6, . . . Land compan(ies) of New York purchased (hundreds of thousands of acres). Parties from Columbus, and other parts of Ohio, also purchased largely of land in the (Maumee) Basin . . . It was only from quicker and fortunate disposal of timer or land, that profit resulted."

Knapp, Horace S. (1872)

"During the flush times of 1835 and 1836 paper money ruled all values. A spirit, adverse to making money by the old methods, was rife throughout the land. There were very few manufacturing or mechanical establishments. They were not in demand; and if they had been there were none to operate them. Farmers had mostly deserted their fields; mechanics their shops; physicians and lawyers, to a considerable extent, their offices; and even many clergy men their pulpits--all classes and conditions of people becoming seized with the fever of speculation, and gathering speedy wealth by means of their wits."

Slocum, Charles E. (1905)

"The savages had no right to this territory."

1838. Fabin, W. W. (1968)

"Old Popquaw wanted to say goodby to little Caroline Farnham who had come with her family to see the Indians take their leave and to bid them farewell. In fact, a number of families had gathered for the same purpose. As Chief Popquaw stepped out of line to shake hands, a soldier shot him down in cold blood."

" . . . as for (Chief) Menominee . . . the soldiers succeeded at length in throwing a lasso over his head."

1838. Bauman (1954)

"Chiefs Ottokee and Wauseon lived but a few years after their removal and died at a comparatively young age."

"Chief Chano: Charloe the Speaker . . . Leader in Indian Resistance to Removal . . . eventually found his way, with a number of Maumee Valley Ottawas, to Walpole Island."

Knapp (1872)

"Lots and lands were offered for sale for taxes; but very small was the amount sold. This was especially the case in 1838, 1839, and 1840."

1844. Scott, V.W. in Van Tassell (1929)

"Toledo was little more than the dead carcass of speculation. Its previous existance had been abnormal, but its condition was worse than negative. It had acquired a widespread and almost universally-believed character for insolubility."

Slocum, Charles E. (1905)

"Early in the 1850's the British shipyards became acquainted with the superior qualities of size, solidity, and toughness of the oak timber of this Basin, whereupon an increasing tide of . . . Timbermen . . . mostly French from Lower Canada, swept up the Maumee River each year to Defiance as their headquarters. These purchasers after cutting the timber as fully as they thought desirable would sell the land to others at a great advance . . . This process has been repeated a number of times, first with the oak timber and later with the softer woods. This work continued actively for a third of a century, with twelve to fifteen years in the decline. The heavy growths of elm (at first) were thought valueless, and in the clearings they, with noble growths of hickories, black walnut, ash, and maple that were in the way were cut down and burned with the brush.

They betokened the advent of a numerous population of tillers of the soil."

Stacey, C.P. (1967)

"A Half Century of Near-conflict."

"The outbreak of the Civil War . . . brought on an Anglo-American crisis that lasted 10 full years. This grim period was ended only by the Treaty of Washington of 1871."

Summers, B. in The Firelands Pioneer (1871)

"The forest disappeared before the sturdy woodman's ax, mother earth felt the warm sunshine in her bosom after untold ages of deep cold shade. Her sturdy ribs were tickled with the rude bull plow and crotch limbed harrow and she kindly gave forth civilized food and comforts for her industrious children. This is the heroic, the Pioneer age."

And the wiping out of algae will be even heroicer.

1859 Kaatz, Martin R. (1952)

"County Commissioners were given the right to enter upon and appropriate the land of any person for a ditch drain, or water course whenever in their opinion the same would be conductive to public health, convenience, or welfare."

"From the beginning the settlement in the Black Swamp the entire agricultural system revolved around corn."

"In many cases only one year after settlement taxes levied for ditches often amounted to the original price paid for the land."

1857. Scott, J.W. in Van Tassel (1929)

Now the population (of Toledo) is not less than 12,000 with abundance of business for a good support to all who are willing to work.

1866. Toledo Health Office, Annual Report (1867)

"All of the lots in the city having standing water on them have been reported to the city council, and nearly all of them ordered to be filled or drained . . . . During the month of August, a disinfectant, prepared under the direction of the Board, was distributed through the streets and alleys of the city."

"London	1845-55	1 death/39 population
New York	1860-64	1 death/39 population
Toledo	1866	1 death/60 population"

1870. Kaatz, Martin R. (1952)

"In some counties less than thirteen percent of the land had been cleared."

Leeson, M.A. (1897)

1853 Wood county	86% timbered
1870 Wood county	68% timbered
1887 Wood county	17% wooded

1875-6. Ohio State Fish Commission. 1st Annual Report

"The Maumee River has for nearly two months been covered with ice, rendering the water cold and clear."

Division of Water, Toledo, Ohio (1938)

"From the time of its inception in the year 1873 and until 1910 the water works plant pumped raw water from the Maumee River into the city mains." Crude and inefficient filters that were first built "as a part of the original system were replaced by a new and modern Filtration works."

Slocum (1905)

"The removal of the large and dense forest growths, the clearing, ditching, and underdraining of the lands, have wrought great change in these rivers. Following heavy or continued rains, and the rapid melting of the deeper snows, the streams rise, and fall, with far greater rapidity than formerly, and generally decline to a lower stage of water during the dryer seasons."

"The water of these rivers is seldom clear, except at the more sandy and gravelly sources. Like all streams flowing through fertile soil the waters contain, largely in suspension, more or less of the constituents of their beds and shores, and the color of the water is varied thereby. In wet seasons the turbidity is very conspicuous."

". . . the waters of the St. Joseph average clearer, and maintain a greater volume in dry seasons than the others."

". . . the waters of (the Tiffin River) in its upper course being clearer than in most of the streams in the Maumee Basin, and a more uniform flow is maintained."

". . . (River St. Mary) waters are sluggish and muddy in much of their course."

"The Auglaize River discharges large quantities of water in wet seasons but is greatly reduced in dry seasons. In fact it. . . ceased to flow from many miles south to its mouth from the latter part of July, during August, and until near the middle part of September, 1895."

1885. Cook, J.D., Consulting Engineer, in Waggoner (1888)

"It may seem paradoxical to suggest that the normal condition of the Maumee water is gradually improving and becoming less objectionable as a source of public supply, that the added pollution due to the increase in population upon its watershed may be more than neutralized by the reclamation of its forests, the destruction of wild vegetation, etc. That the immense system of ditching which has been carried on during the past several years, tends to the more prompt discharge of rainfall into the River, and its tributaries resulting in more rapid current and more sudden and greater floods--all beneficial in thoroughly and frequently cleansing the River channel from the various impurities accumulating along its shores during the season of low water and less rapid flow. Tiling, which has been adopted as a means of underdrainage, and even now almost incredibly extensive, is destined to become universal throughout the entire watershed or drainage area, the time will therefore doubtless come when these countless little pipes will furnish a very large percentage of the ordinary River flow, with water almost universally clear by filtration through the soil--the organic impurities, the albuminoids, etc., being retained in the earth as the life giving essence of vegetation.

As the resulting effect of above mentioned causes, we have the visible and well known fact that in former years the River at many or all points below Miami Rapids was not infrequently covered, during the warmer summer month's, with an offensive coating of scum of decomposing organic matter drawn from the water by capillary attraction - conditions which now very rarely (and never to any great extent) occur."

The Maumee River as an improved Crapper.

26 June 1879. Field and Stream, J. B. B.

". . . warm and muddy waters of Sandusky Bay."

1893. summer. Kirsch, Phillip H. (1895)

"The water in the Maumee River and that of its larger tributaries is rather clear, while that in the smaller streams, on account of their clay channels, is more or less turbid."

1903. Slocum, (1905)

"The great increase in the number of Petroleum and Gas wells about the city of Findlay, and particularly above and along the Blanchard River from which the water supply has been largely obtained, has led to intolerable pollution of the water in the ditches, creeks, and river, by the pumpings from these deep wells of great quantities of water highly charged with the mineral salts and by impure Petroleum.

A new source of potable and culinary water supply became imperative."

Anthony, D. L. (1922) in Sandusky Registrar Centential

"The fishing industry reached its zenith about 1854."

Autumn, 1881. Howell, D. Y. (1882)

At the time they were obtaining whitefish spawn from the reef area off Locust

Point they "were visited by a freshet of such magnitude as to swell the various streams, which, empyting into the lake their muddy waters drove the whitefish and herring entirely off the shore into deep and clear water . . ."

Moore, H. F. (1894)

Lake Erie

"Michigan Shore: the water is muddy and considerable shoaling has taken place since the hydrographic survey of the region.

Maumee Bay and River. The seine fishery on the river was formerly of considerable importance, but has of late years decreased, as the fisherman suppose, on account of the petroleum which passed into the stream from the oil fields. In seasons of drought . . . the water is stagnant below the rapids and the fish do not come up stream from the bay. The ice leaves the river before the bay is clear and saugers are taken in the seines as early as the middle of March . . . . Sometimes, although not within recent years, considerable numbers of herring are caught in the bay.

Upper Cedar Point to Locust Point.

Sturgeon were formerly very abundant and a few are still caught, formerly there were good runs of herring as early as September and of whitefish in October.

Locust Point to Marblehead Herring were at one time caught east of Scott's Point in the spring. Herring are, or were, the principal fish during the fall. Whitefish were formerly an important item in the fall catch, but are much less abundant than they were 20 years ago.

The Island Region . . . a large portion of the inhabitants are dependent more or less upon the fisheries . . . gill net tugs from eastern ports swarm here in the fall . . . Every available site for a string (of pounds) is occupied.

Sandusky Bay. The fisheries are extensive. Carp are increasing. The water warms rapidly in the shallow waters of the bay, and it is necessary to remove the nets about May 25.

Herring. West of Sandusky, on the mainland, the herring began to disappear about 1889 and 1890, and from that time the catch rapidly decreased.

White fish. As compared with the decade ending 1880 this species has decreased greatly.

Catfish. There evidently has been a heavy decrease in the catfishes (in the past 10 years).

Sturgeon. (Great decrease in past 15 years.)

Walleye. There has been but little decrease in this species, excepting in the larger sizes.

Sauger. This species has probably decreased to some extent.

Perch. The total catch of perch inthe spring is very considerable.

Remedies. Federal restrictions on fishing."

Notes by B. L. Hardin

5 Sept. 1894.

Dredging trip with "Shearwater" (on the West Reef)

"The most salient feature of the results was the marked absence of animal or vegetable life on the bottom.

Sandusky. Mr. Stoll told the old story of so many gill nets getting lost during stormy weather, the nets continuing to fish until they dropped to pieces. A "half sturgeon" is one under 4 feet long."

3-19 May 1898. Cooke, Jay in Pollard (1935)

"Fishing 'non est' as storms and floods have stirred up the lake and the fish will not come until the lake clears up."

This, the only year of comment by Cooke of unclear water, is the year of Pieter's survey of aquatic plants at Put-in-Bay.

General Critchfield in Downes (1950)

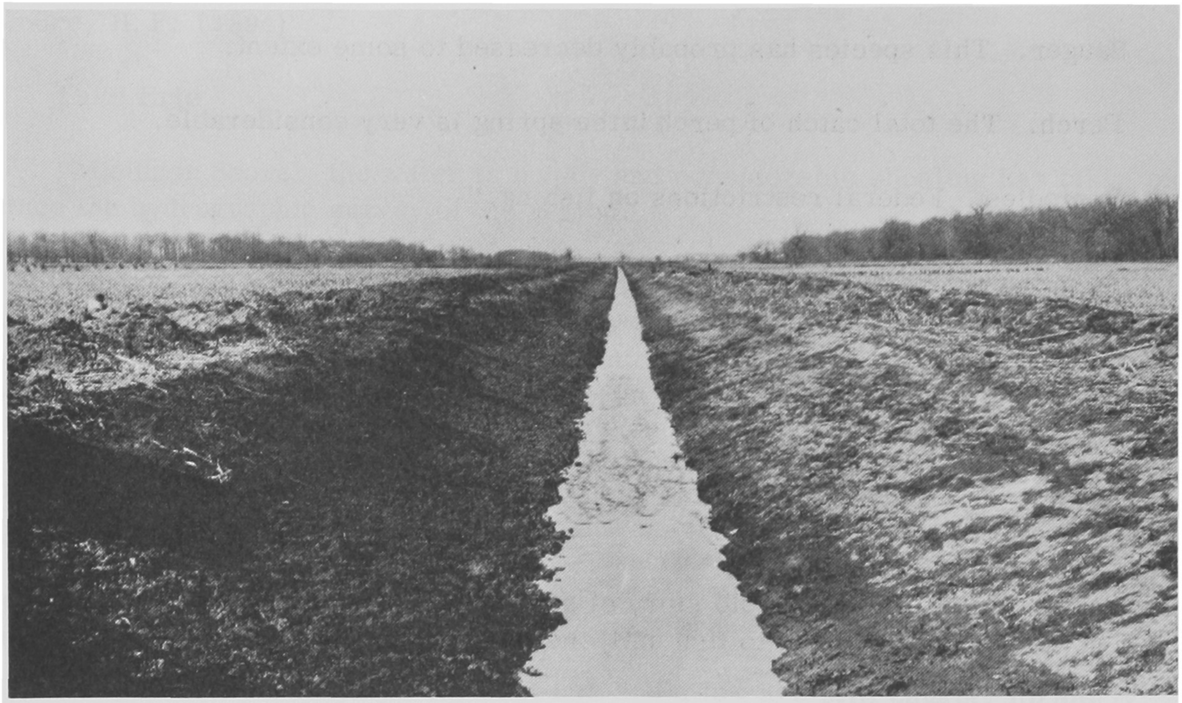
"We will get the camp (Perry) so dry that the bullfrogs will have to carry canteens."

Grant, G. M. (1922) in Sandusky Registrar Centenial

"The odors and sediments of oils, sewage and wastes have so found the water and bottoms in localities, notably the entire west end of Lake Erie, that fish can no longer find food or live in poisoned areas. It is a common sight to see thousands of dead fish floating on the surface, and the same conditions obtain along Lake Erie's entire coastal front."

Figure 5. Drainage outlets in Maumee River Basin. a. Excellent, b. poor.

a.



b.

Photographs courtesy of Ohio Division of Water.

Poston, H. W. and M. B. Gamet (1964)

"The most serious treatment problems (in the Great Lakes) are associated with low turbidity, water temperature, and inadequate sedimentation periods . . . The short filter run problem is most severe when turbidity is low (so that sunlight penetrates to greater depths in the water), water temperatures range from 45^0 - 60^0 F, and peak demands are experienced."

FWPCA Lake Erie Report (1968)

"The most damaging substances affecting the total waters of Lake Erie are nutrients . . . . Other substances having damaging effects on the total waters of the lake are suspended solids (sediment), and carbonaceous oxygen-consuming materials."

4 June 1968. Wright, Col. Amos L.

"Now, I should make it clear that not all the material to be dredged is polluted. . . where the FWPCA has determined that there are no significant pollutants in the material to be dredged, the clean dredged materials will be placed in the authorized disposal areas in the lakes."

22 September 1970. Toledo Blade Pollution Solutions.

"Fighting Pollution is Good Business."

"When the Maumee is free of industrial and municipal pollution and safe for swimming and water sports, Mr. Skeldon concedes that it will be muddy because of the siltation problems. Clear Water proposed in 1967 a Department of Agriculture watershed project for Swan Creek, a Maumee tributary. A work plan was drawn up which calls for bank cleaning and stream straightening along the upstream portion of the waterway."

Langlois, T. H. (1954)

"The shallow western part of Lake Erie appears to be the key area for starting the conversion process which culminated in crops of fish."

BACKGROUND OF CLADOPHORA IN WESTERN LAKE ERIE

Atagib (Algonquian) or Cladophora - which is to say windrows of the stinking moss or, as we have been corrected, algae on the beach - is a result of pollution in Lake Erie. "Everybody knows this." This assumption is to be reviewed.

Fjeringstad (1965) in a survey of Cladophora glomerata (L) Kuetz. found it "as a rule is associated with clean water", but that it tolerates a certain degree of pollution and will then grow more vigorously. It cannot be said to belong to (a more grossly polluted) zone, where it may be met with, but leads a rather miserable existence. . . As to the occurrence of the species in lakes, it will be more accurate here to regard it as an indicator of eutrophication than as an indicator of pollution. . . We can only say that an eutrophic habitat is one with a high pH where available organic matter is rapidly reduced to an abundance of the vital mineral elements."

When did this alga appear in the region that now encompasses the western basin of Lake Erie? There is reason to believe that it was present in preceding glacial lakes and tributaries from the south and west. Glacial melt mixed in a limestone basin with drainage off swamps to the south is suspected of being a highly permissive Cladophora habitat. In the present study it has been found to photosynthesize within a degree of freezing and to grow at temperatures down to 40^0 F.

When the glacial dam melted at the Niagara sill some 12,000 years ago, water spilled and its surface was lowered 165 feet, which was 130 feet below the recent elevation of near 570 feet (Lewis, 1969). During this early Erie stage the substrate of the western basin was rock outcrop, some till, and mostly compacting mud flats that were gullying and draining poorly above the lake level (Hartley, 1961).

Lake Erie's history has been stable compared with the region's lakes of the preceding Pleistocene Epoch. However, there have been geologic events that affect Cladophora abundance by changing the extent of solid substrate in its photic zone, also the sources of nutrients have changed. The underlying circumstance has been Lake Erie's westward inundation with the diminishing rise of its unloaded Niagara sill. Submergence of the western basin began some 4,000 to 5,500 years ago. It escalated with the reversal of the Detroit River, bringing water from the uplifted upper lakes. Water deepened some 15 feet over the Niagara sill. The Detroit River enlarged over a period of several thousand years as the other upper lake drainages, The Ottawa River, Ontario, then the Chicago outlet, were being abandoned. Its portion of the total surface flow into the western basin increased from 0 to over 95%. Thus, while the aquatic photic zone was expanding the aquatic medium was freshening.

The maximum area of rock substrate in the western basin was probably attained when water levels averaged some 4-5 feet lower than at present. This occurred after Lake Erie was receiving all the drainage from the upper Great Lakes or after 2,500 BP (Stevenson, 1969), and before the earliest French exploration. Since then the amount of rock being submerged at shoreline has not kept pace with the amount of deep rock being buried by sediment.

Hydrologic data suggests that, during the six thousand years previous to inflow from the upper lakes, evaporation exceeded combined runoff and precipitation into Lake Erie during late summer and autumn (Sanderson, 1966). An ecosystem matured in this environment while the western basin was submerging. As an expanding sink in a basin of highly productive flats, was the cradle of the western basin communities sparse in nutrients?

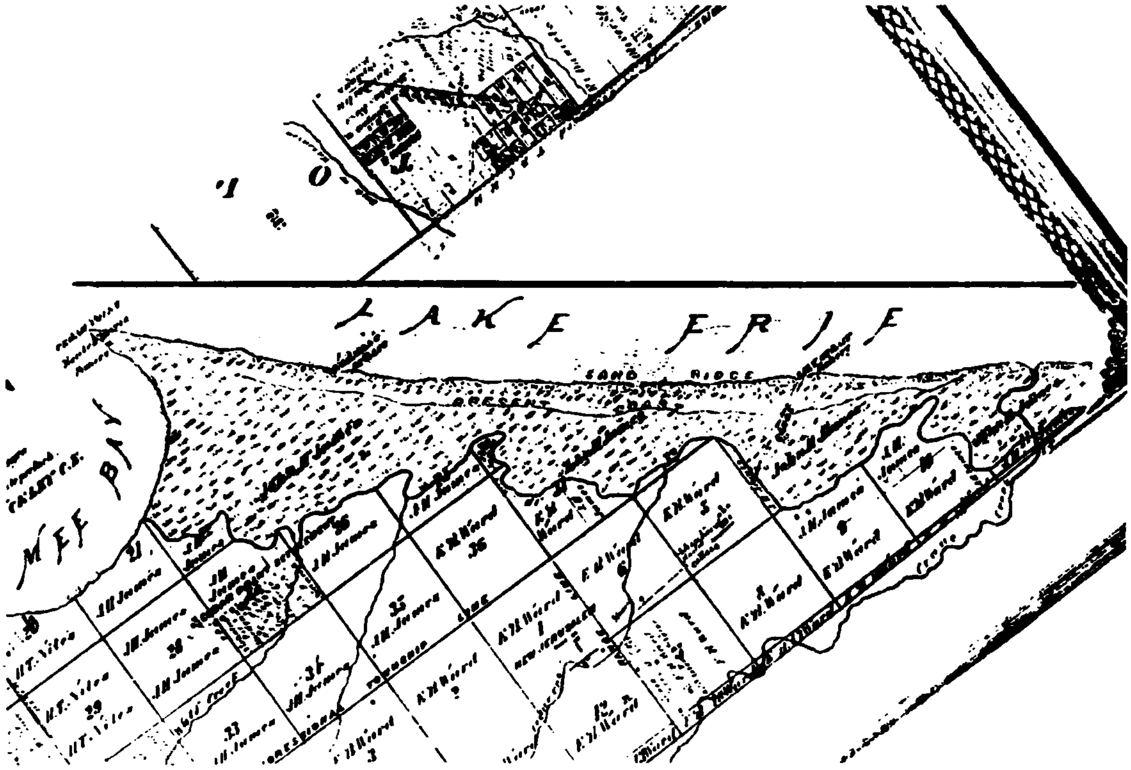
Fashion dictates that Lake Erie be lean, pristine and muddled "like it was." Four sources of nutrients for precivilized western Lake Erie seem forgotten: the watershed, drowned river mouths, retreating barrier beaches, and the shallow lake bottom. Erie was an Indian name of a healthy cat.

Swamps and wet prairies almost totally occupied the watershed. "Putrifying" was the description commonly given to the standing water during late summer and autumn. This description held for stretches of running water draining hundreds of square miles. Only over the hard substrate of the major branches of the Maumee system does there appear to have been a "recovery zone" where water cleared. It is quite possible that the "fecundatings" of this season's everpresent "green scum" below the Maumee Rapids were algae thriving on mineralized solutions. While this was the season of low flow, low flows were considered higher than after land clearing and ditching. During high flow, running water appears to have been generally clear, in great contrast with today. With the elimination of autumnal organic solutions came the spring muds.

By the time of inundation the western basin's tributaries had been mostly excavated and their base level raised 80 feet. Since then the rise in water level has averaged about 0.1 inch per year. Drowned river mouths were barred from lake waves and their rate of fill with dead vegetation would have easily kept pace with rising water except that erosion rates were evidently similar to rates of fill. Descriptions of organic wash here were made during the low flow season. It seems probable that there was erosion also after ice thaw. Ohio cattail beds fill at the rate of about an inch a year. At this rate the contribution of organic matter from drowned river mouths to the soft bottom of western Lake Erie would be of the same order as the rise in water level. Wild rice, not cattail, mostly filled these bays and their contribution was probably slightly less. Organic wash was buried, or was assimilated and oxidated increasingly as organic loads per volume of lake water decreased, or was passed on to the central basin decreasingly with retreat of the stream mouths. The multiplication of stream mouths has lessened an increasing open water to bay ratio. This source of nutrients was also largely destroyed during settlement after the Civil War and has become another source of suspended mud.

The shoreline of the western basin is largely, and it is assumed always has been, a retreating sand barrier beach. The beach barred black muck that had been accumulating behind it for upwards to a thousand years or more. The rising water of northeast storms have pushed the sand veneer landward releasing muck to the lake and often coinciding with till buff erosion from the Colechester headlands. This contribution to the soft bottom also has been of the same order as the rise in water level and has been declining with the length of barrier beach to area of open water ratio. Retreat of the beaches has continued since the first land surveys, but the "meadow" or "green belt" surrounding the lake has been squeezed, laterally by towns and on the land side by roads. Ditching, dyking and construction have altered the nature of the belt.

Figure 6. Lucas County, Ohio, Oregon Township shoreline.



From an Illustrated Atlas of Lucas and part of Wood Counties, Ohio. 1875. Chicago, Publ. by Andreas and Baskin.

Irwin and Stevenson (1950) widely demonstrated the coagulation and settling of suspended clay by hydrogen ions released from rotting vegetation. Their rule of thumb for Oklahoma standing water in summertime is two parts of dry vegetation are required to settle one part of suspended clay, without critically depleting dissolved oxygen. During the last third of the 19th Century, the activities of pioneers ravaged the organic to clay injection ratio that has affected western Lake Erie turbidity and the mud bottom accordingly.

Lake Survey charts indicate the bottom topography of the western basin has not changed generally over the past century despite the huge clay and silt injections. Sedimentation is controlled primarily by wind action on the form of the basin. Much of the mud bottom settled early (Herdendorf, 1969). Lake mud columns have clay fractions commensurate with surrounding till except at the surface where there is generally no clay. This suggests that no clay is settling and/or clay has washed away from there. Also, "black mud" was entered at times with sounding descriptions into the field books of the first Lake Survey in the 1840's. The same mud areas are tan or light gray today. In fact, the top seven or more feet of mud is relatively low in organic matter and it is suggested here that it had settled there with the clay and has oxidized since the destruction of the organic hoppers for the mud bottom.

Early writers noted the Lake Erie green color was not as dark as the other Great Lakes except Lake St. Clair. More yellow was due either to higher concentrations of humic acids (Hutchinson, 1957), or reflections off bottom vegetation. No mention has been found of a difference in water clarity between western Lake Erie and the rest of the lake that has been obvious the last four decades, except when the bottom was resuspended by high winds, as happened in Lake St. Clair. The description by Hopkins strengthens a belief that clarity of western basin waters was similar to that of waters to the east. If so, turbid darkness did not prohibit a mud bottom vegetation.

Rooted aquatic vegetation was confined to depths less than 11 feet when western Lake Erie was surveyed by Pieters (1901). One could spend, in fact one has spent thousands of hours in vain looking for descriptions of offshore submerged vegetation before pioneer mud injections. However, some explanations are needed in connection with the question - was the mud bottom of the western basin generally vegetated at that time? In other words, is the depletion of submerged vegetation since Pieters' survey (Stuckey, 1969) a minor continuation of depletion that took place in the several decades preceding his survey?

Earlier descriptions around the Bass Islands suggest a depletion of emergent vegetation by Pieters' time. The field drawings of earlier Lake Surveys occasionally included emergent vegetation on the lakeside of barrier beaches. Offshore vegetation has noticeably decreased in the Toussaint area during this decade (Virgil St. Clair, personal communication). Submerged vegetation succeeded emergent vegetation in the rising water of the western basin; it did not succeed the bottom of today.

The entire soft bottom of Lake St. Clair, 21 feet deep, was considered abundantly vegetated with Charophytes before extensive clearing in that watershed (Pieters, 1894). Yet, Lake St. Clair had received hugh sediment loads from the emerging south shore of Lake Huron (Leverette and Taylor, 1915). Was the bottom of Lake St. Clair that much more permissive to a submerged vegetation than western Lake Erie, which is essentially less than 36 feet deep?

Probably, areas of black mud and most of the mud bottom of the western basin had more oxidizable debris than in recent decades. During the rare stagnant periods of summer stratification was there oxygen depletion and a holocaust of high oxygen dependent benthos as in 1953? (Britt, 1955). Was there sufficient photosynthesis in the lower layer of water to offset oxidation, by phytoplankton or by bottom vegetation?

Amongst the numerous early comments on lake water appearance there has not been found any description resembling "pea soup" until the mid 1890's by Kellicott (1896) at Cedar Point. Was the organic wash of late summer too poor in nutrients or was there a different blue-green phytoplankton control? Was the control in the water column or on bottom? Could bivalves have maintained blue-green populations at inconspicuous levels or was mud bottom vegetation required for the establishment of phytoplankton filterers? Hasler and Jones (1949) noted there is also an inhibition of phytoplankton by bottom vegetation.

Jay Cooke was famous as a smallmouth bass fisherman (Pollard, 1935). He preferred fishing in deep water 18 inches off bottom, yet upon his return to Gibraltar in 1881 after 7 years absence his excursions were to reefs and further afield. Was there a benthic change in deep water around the Bass Islands? This was the era of fish hatchery building following general fish depletion in western Lake Erie.

The changes in turbidity and the mud bottom have lessened the extent of Cladophora and possibly modified its density. Cladophora glomerata was identified from Lake Erie (Bailey, 1848) apparently a third of a century before the second alga was. (Vorce, 1882). This may reflect on its former conspicuousness. Sidney I. Smith (1871) dredged in Lake Superior when the water temperature at surface was 50-55^{0}F, and below 30-40 fathoms it was 39^{0}F. He found,

"Simmons Harbor on the north shore of the lake, about 12 and one-half miles north-northwest of Otter Island, August 9, 13 to 15 fathoms, bottom of fine sand with scattered tufts of a small alga of the genus Cladophora."

"In a small harbor on the south side of St. Ignace Island, between the main island and a smaller one, and due south of St. Ignace station, September 4, two hauls 8 and 10 to 13 fathoms, a little sand and mud brought up with great quantities of the same species of alga found in Simmons Harbor, and which, according to Professor Eaton. who kindly examined it for me, is a small densely tufted species of Cladophora, possibly C. glomerata Linn., a most variable species, but the specimens do not well correspond with authentic ones from Germany. This algae was brought up in immense quantities, the dredge being full at each haul."

Figure 7. Cladophora on rocky shore, Gibraltar Island, Lake Erie.

Photograph from the J. Cooke Collection, Courtesy of the Ohio Historical Society Library, Columbus, Ohio.

Cladophora was in the Niagara River "everywhere where the current is strong" (Day, 1882). Summertime photographs, along with Pieters (1901) indicate it to be abundant around the Bass Islands between 1865 and 1907 (Appendix A). Numerous Stone Laboratory papers mention the summertime growth of Cladophora after 1930 (Kishler, 1967), but little was noted of the cool weather crops.

Kalm (1749) commented on filamentous algae," hich grow in plenty" found in bellies of Hudson River sturgeon. Harkness and Dymond (1961) cites lake sturgeon for the control of pond algae. Sturgeon were gone from Lake Erie before we learned of their effectiveness for Cladophora consumption. It is doubted that they can break down the filaments and probably depended on the included invertebrates for sustenance.

If Cladophora ever suffered from competition for nutrients, or from inhibition, in the well-mixed waters of the western basin, it went with the virtual elimination of other bottom vegetation, especially species without developed roots such as Charophytes. Stuckey (1969) has found the species of higher aquatic plants reduced by half in this century at Put-in-Bay. Pieters (1901) found 9 species of Charophytes around the islands; Wood (1947) found 4 species; none have been found in the last decade despite an increase in diving.

A mud bottom vegetation could have provided a barrier to frequent floc movement across the bottom over which detached Cladophora tufts and its community were draped. Renewed growth during cool periods would have been expected there until filaments were coated or buried by resuspensions during storms.

The main competition that now remains for the spring crop of Cladophora is a dying pulse of planktonic diatoms. Major nutrient sources in the spring are stirred-up lake bottom, the southwest watershed and Detroit outlets. It is the spring Cladophora crop that some residents of the Bass Islands say increased after World War II. During the 5 years of this study, it is not imagined that a lack of nutrients has limited the spring crop, and Cladophora production has not been affected by annual variations in river discharge (Table 2) or diatom abundance.

Major nutrient sources for the autumn crop are decomposition products of late summer algal blooms and various bottom communities and Detroit. The great variability of this crop is possibly remotely inverse to nutrient concentrations. Cladophora germination is critical and seems dependent on the thinness of a rock coating of remains of blue-green algal blooms.

The amount of suspensoids now added in the spring by the Maumee River are enough to constrict the photic zone above the floor of accumulation and confine bottom vegetation to the margin of the western basin (Verduin, 1954). Lack of light has not permitted the growth of attached Cladophora on deeper rock within the past century. However, the lower boundary of growing Cladophora has been extending slightly deeper in each of the past 6 years and probably longer. Annual and areal distribution of the lower boundary depths (Table 6) reflect on suspended mud turbidity. Two exceptions emphasize this rule. During the high water of 1968, '69, and '70 the lower boundary was several feet shallower along the southeast shore of South Bass Island as inshore waters were kept unusually turbid by eroding till. During the cool June, 1969, growth continued after maturation and the lower boundary extended several feet deeper in the clearer waters of that month (Figures 13 and 14).

The gradual extension of Cladophora's lower boundary suggests that seasonal light penetration is primarily controlled by a gradually rising floc capacity of resuspended bottom. This was not true during the period of the studies of Chandler and Weeks (1945) and Verduin (1951), when springtime turbidities were considered to reflect primarily on tributary discharges. Seasonal nutrient concentrations in the water column also are affected by suspended solids (Pfister et al., 1968) and are subject to the same change in control between the two periods.

Phosphorus concentrations around the islands are probably always at luxury consumption levels for Cladophora (Sawyer, 1947) (Table 7). Depending mainly on wind-suspended sediments, phosphorus levels varied 24 fold over the Peach Point shoal during 1965 and 1966. The ratio of soluble to insoluble phosphorus remained fairly constant at approximately 2:1. Seaman (1952) reported that Cladophora absorbed large amounts of phosphorus from fertilized Lake Erie water, thought to be in excess of its metabolic requirements. This suggests that Cladophora could thrive if it received sufficient nutrients only during times of muddy water.

It is necessary to arrive at a conception of open water turbidity and mud bottom conditions over the past century for perspective on recent deepening growths. The view taken here is that there have been three productional stepdowns taken as established mud bottom communities are eliminated by increasingly intolerable conditions with invasion of more tolerable communities in the interims.

The period from possibly the 1870's until 1925 followed the elimination of mud bottom vegetation. Water was not as clear then as previously, but with this period went the island pastime of watching smallmouth bass spawn. A stepped-up digestion of stored organics on bottom, presumably, began with this period. By comparison, it lasted at least ten times longer than the good production period of newly dammed reservoirs while previous field vegetation is being oxidized.

Sludge deposits in fish hatchery tanks, that received water off the west shore of South Bass Island, began in 1925, except for stormy periods, and grew steadily worse (E. Miller, hatchery employee, 1918-63, personal communication.) Secchi disc readings of over 10 feet were rare and possibly obtained only with influx of outside waters during the period 1925-53 (Wright, 1955; Chandler, 1942; Verduin, 1954). Flocculation of injected clays seems to have been less in the western basin. It is evident that for more than a half a century after the elimination of mud bottom vegetation a large portion of the floor remained coherent enough to support burrowing Mayfly nymphs (Britt, 1955). Dredge samples clumped such that they were broken to examine the Hexagenia burrows (Britt, personal communication). Bottom samples have been a viscous fluid since then. Before the Mayfly extermination there was commonly a mat of sulfur "bacteria" buried at the oxygen - hydrogen sulfide interface (Randles, 1966). Sparse filaments of the Thioploca have been found since (Randles, personal communication).

On 10 June 1963 Mr. Tim Luecke, captain of the 63 foot Erie Isle Ferry was sailing on 27 feet of water off Green Island. A dead calm was disrupted by a southwest storm. Within 5 minutes waves had built enough for the propellers to stir up bottom mud. Divers can become engulfed in darkness by a slight wave of the hand over the bottom. There may be solids movement across the bottom with changing water levels at twice the seiche interval of 14 hours.

The suspicion is that the bottom lost coherence following the kill of the Thioploca-Hexagenia community, then became fluid and unstable mostly during autumnal storms of 1953, and has since become increasingly flocculent. The recent observation that the lake now clears more quickly would be explained by stirred-up and settled flocs absorbing finer suspensoids. During June and July, 1968 and '69, a 9 inch diameter white bucket was commonly visible at depths slightly over 10 feet east of Ballast Island. (But in 1970 Secchi disc readings over 10 feet again were not obtained.) Using Lambert-Beers Law with Verduin's (1954) Lake Erie constant, the annual deepening of the spring crop of Cladophora equates to 3.6 mg/L less suspended particles per decade. At this rate of clearing Cladophora could occupy nearly all the unsilted and unpolished rock in the western basin within 3 decades. However, clearing rates are expected to lessen as total suspensions lessen.

Tubificids have less competition in a fluid substrate than a firm one. Regional populations were less than 100 per square meter in 1929 (Wright, 1955), more than 25,000 per square meter in 1966 (Smith, 1969), and appear to have increased in numbers since 1966 (Smith, personal communication). They are active the year around. Their daily castings in loose form total 4-6 times their body weight (Alsterberg, 1924). Their deposits figure to be of the same order of magnitude that Herdendorf (1969) found for deposition (and erosion) on neighboring reefs -- approximately a millimeter per day. Activities of benthic organisms promise an explanation to floc development.

Frail planktonic streamers an inch or so long and separated by several inches of water sometimes surround the islands during June and July. Their role in Lake Erie awaits description, as does public enemy number one-fertilizer.

The theoretical location of mud passing through the western basin is summarized:

Period	Suspensions	Deposition and Erosion
1870-1925	Increasing	Increasing
1925-1953	Increasing	Decreasing
1953-present	Decreasing	Increasing

THE LITTORAL ZONE AROUND THE BASS ISLANDS

The shallow water area that supports attached Cladophora is considered the littoral zone here. It extends from the waterline or 3 feet above, being higher on more vertical slopes, to a depth ranging from 5 feet at Catawba Cliffs to 14 feet at Kelley's Island Shoal. A consideration of Plectonema would modify the littoral zone definition and extend it to a depth, in places, of partially silted rock - a bivalve zone. The acreage of the littoral zone varies with water levels and can be estimated from Table 4.

The substrate of the littoral zone is predominantly stable dolomite: bedrock strewn with boulders, angular cobbles and pebble talus and pockets. East shores are mainly eastwardly dipping shelving, and west shores mainly bluff. There are a few unstable beaches of rounded pebbles beneath bluffs, and sand on shelving. The underlying stable rock at unstable beaches usually becomes exposed near the 562.6 (IGLD) foot contour line of USGS quadrangles. Ponds and some bays have silted substrates that favor rooted plants, or that have become increasingly devoid of macrophytes as at Put-in-Bay, Ohio.

Currents over the littoral beds are oscillating and longshore or rip in places, and vary extremely in intensity with locality and weather.

Attached algae lend seasonal aspects to the stable littoral zone of open water, with growths on shelving being slightly in advance of bluff growths. After spring ice-break, the zone is scrubbed clean except for sparse Cladophora that may remain from the previous autumn and for Ulothrix zonata (Weber and Mohr) Kuetz. growing along the shoreline. The brilliantly green Ulothrix spreads upwards with rising water levels and is the only vegetation apparent except for occasional patches of filamentous blue-green algae. In 1969 the red Bangia atropurpurea (Roth) Ag. was established and extended its coverage in May and the following spring (Kishler and Taft, 1969).

New Cladophora growth can be found when water temperatures exceed 40°F and the lake clears somewhat. Widely scattered and slender Cladophora filaments are masked by Ulothrix, or they form dense mats next to sharply defined lower boundaries of Ulothrix, or as new filaments on overwintered tufts of Cladophora. The main bloom comes on between one and four feet deep as water warms to 50°F, then advances upwards weakly into crevices or on overwintered tufts. However, after the first bloom becomes solidly established, downward spread is at a surprising rate in a complete and uniform cover, or in bed-lobes which later fuse. The deepest penetration is reached near the end of its phase of protoplasmic growth at a water temperature near 65°F. Filaments are clean during this phase and the beds harbor a very few large gammarids, and larvae of beetles and midges. Occasional bright green patches of Stigeoclonium are evident along the shore.

As water temperatures approach 60°F, about 1 June, Cladophora cell walls become layered. This is accompanied by carp spawning. Single eggs stick an inch or so apart on filaments and on many eggs is soon developed a fungus halo. During this week there is an astonishing development of a teeming community. The Cladophora bed covers populations of desmids, protozoa, rotifers, nematodes, flat worms, oligochaetes, copepods, larvae of beetles, midges and caddisflies, mites, gammarids, and snails along with epiphytes.

Carp rooting activity is responsible for detachment of algal filaments between 60^0F and 65^0F. Cladophora becomes "ripe" enough to detach without outside influence above 65^0F. Detachment is usually associated with high winds, but the deeper portions of beds and leeward beds may lose as much as those exposed to a storm surf. Detached tufts are either driven to beach or drift along shore until currents leave the shoals; some storms characteristically littering beaches and some cleaning them. Storms are not necessary for detachment as mild winds can drive large volumes of short filaments to shore. Gas bubbles adhere to the alga on calm, sunny days and they may exceed the filaments in volume. The pull of buoyancy is enough to break filaments and large tufts float motionless over beds at these times.

Beds progress from fresh, 10 inch thick waving meadows to brush fields browned with diatoms, then to separate, silted stubs of filaments throughout June and July, although in the cool summer of 1969 fresh material remained throughout July. A fresh "down", on remaining filaments, or later on rock, may accompany cool periods during warm months, even when water temperatures are near 80^0F. However, growth does not continue. Tufts at mid-depth or deeper are the last to detach.

While filaments are being detached in late June, a new growth of Cladophora becomes solidly banded along shoreline above the beds. It remains attached and fresh throughout the summer and autumn. The accompanying community, while more diverse and populated more heavily than the springtime aspect, is not usually prolific. However, over a thousand gammarids per square foot have been noted in the cover on shelving. Stigeoclonium is occasionally on these filaments.

Other algae invade the littoral zone at isolated communities during the latter part of July. Membranes of Tetraspora lubrica (Roth) Agardh. form green beads on denuded rock near the water surface. Blue filaments of Asterocytis smaragdina (Reinsch) Forti attach to shallow water Cladophora filaments and neighboring rock. Rhizoclonium fontanum Kuetz. becomes immeshed at mid-depth and has the appearance of fine new Cladophora filaments. Large, dark threads of Plectonema wollei Farlow, and finer blue-greens become entagled even on bare rock in deeper water and form extensive beds of algal cover. Rocks with a dead appearing "skin" support numerous dark brushes of an Oscillatoria.

The Cladophora community generally leaves with its algal cover in summer but lesser populations remain under rubble along with an increasing leech population. Physa can become abundant on shelving shore. The deeper part of the zone becomes inhabited by large populations of corneous and gelatinous bryozoans. Midge cases (Tanytarsus exiguus Johannsen) are common, and Spongilla less so.

A slick, pale coat forms on the rock surface during summer, although some isolated rocks that remain cleaned have a dark green scale of Cosmarium formosulum Noff. The coat appears as a matrix of floc from invertebrate castings and amorphous blue-green plankton remains that supports sparse Gyrosigma, naviculoid diatoms and blue-green filaments. The above mentioned "down" of Cladophora, that sometimes forms, becomes the best binding structure for the matrix and thicker coats then develop. West shore bluffs support a tougher coat than east shore shelving, on which rests a more settled floc.

The autumn Cladophora pulse is initiated in the matrix, and if the coat is very thick, growth is completely inhibited. Commonly, the crop is slowed by lesser coats, also by a rapid decline in temperatures to the extent that it does not grow very deep nor reach a "detachment maturity". The 1966 autumn crop did "mature" and was, in fact, the largest standing crop in the 6 years of observation. One December storm cleaned the shoals and Ulothrix soon invaded the shoreline and overwintered.

Some Cladophora overwintered during 1965, '67, '68 and '69. However, ice action cleaned the shoreline well, except in 1969-70. Ice fishermen have hooked filament drift in the strong currents that develop under ice. Filaments have accompanied ice to beach in windrows at the time of spring ice break.

Downing (1970) described the shoreline algae in more detail.

CLADOPHORA

When Cladophora growth is initiated and appears as a mat, or if fresh growth is sheared close to the rock, filaments can be seen to arise in patches of 10 to 30 square millimeters. A few scattered filaments are outside the patches while inside they are gregarious. The patches, which may occupy half of the rock surface, are not uniformly distributed. Tufts are formed by a dozen or fewer filaments that twine and branch from a rope axis.

The spring pulse has two rather distinct phases, called here 1 - protoplasm synthesis and 2 - cell wall layering. The first phase is of protoplasmic addition accompanied by terminal cell division and branching with filament elongation. Organic dry weight increases at a rapid rate that is seldom found in natural vegetation after water temperatures reach 50°F. Filaments have a somewhat silky texture, and their color grades from a deep green base to yellow-green apical branches. They are not as bright green as Ulothrix or Stigeoclonium, nevertheless it is more saturated than any shade on the Munsell Color Chart.

Microscopically, the dark green basal cells appear dense throughout and have well defined pyrenoids. Reticulate protoplasm with chloroplasts at junctions is evident in the yellow-green apical cells. Although they are large and thick walled for algal cells, they are slender and thin walled as Cladophora cells. The bases of apical cells are a half to a quarter the diameter of cells near the holdfast, some 100 to 5,000 cells back. Cells are three to 20 times longer than broad, being longer at the plant's base. Filaments are straight. Branching angles are straight, at about 25° with multiple branching from a cell, though single branching predominates. Branching is almost always adjacent to the apical cross wall. Evection is none, or to the degree that branching appears dichotomos.

Sporulation is sparse in these cells, but enough to close the bedgaps during the alga's downward extension. Sporulation consists of the concentration of protoplasm, its fragmenting and rounding into spores, not much larger than pyrenoids, that flagellate or pour out a lateral pore that dissolves just below the apical crosswall. Rows of clear cells, devoid of contents, usually have evident pores and are considered to be spent sporangia. They are more common in the apical portion of filaments and more common at a shoreline habitat. Spores recovered from drift material germinated against Cladophora cell walls and on a microscope slide with no determined selection between solids substrates. Fusion of motile cells has never been observed.

Very few epiphytes accompany the phase of uniform development. Cymbella tubes, appearing as dots in branch angles are most common. Filament bases may have a few stalked diatoms and stalked protozoa.

Diverse developments accompany the phase of cell wall layering. Cell enlargements commonly become club shaped. More bizarre forms frequent the deeper growths of the bed and older and blacker cells: mid-cells get bent at a knobby, right angle. Crosswalls slant acutely as that area becomes swollen. The pair of cells at a branching angle fuse part way, then diverge widely.

Branches in warmer water usually arise more perpendicularly to the main branch, then curve to a position somewhat parallel to it. This occurs throughout the filaments, but branches often cease to grow and cells don't divide. It seems to be an expression intermediate between the straight branching of fresh material and sporulation. It resembles sporulation in that protoplasm often concentrates at the apical ends of a half dozen or so consecutive cells and departs simultaneously, but to a branch.

Tuft axes and some branches have tan deposits of silt crystals embedded in the rope. These and/or $CaCO_3$ deposits may make up the major part of the weight of old Cladophora that has been washed. $CaCO_3$ is precipitated from lake water by the epiphyte Gongrosira stagnalis (West) Schmidle (Taft and Kishler, 1968). Gongrosira may bead basal filaments a white or straw color, or envelope the axis, turning green-black as they enlarge.

Filaments become progressively woolier to the touch and duller in color as a chitinous layer forms externally on the walls (Wurdack, 1923). Wall volume, which is mostly of cellulose, can become ten times the enclosed cell volume. These akinetes may be separate or joined in a series.

This is ideal substrate for epiphytes. Cymbella clumps continue growth. Stalked Rhoicosphenia curvata (Kuetz.) Grun is joined by Acnanthes sp. and the stamp-like Cocconeis placentual Ehr. These diatoms can cover the walls to the extent that a golden red is imparted to the filaments. Two other epiphytes become dense and widespread; a dull felt of Lyngbya sp. and the above mentioned Gongrosira. Later occuring epiphytes include a red purple Phormidium sp. where there is nutrient enrichment. Downing (1970) includes a more extensive list. Stalked protozoa increase as the season progresses. They include, in numerical order:

1. Epistylis, 2. Tokophyra, 3. Rhabdostyla, 4. Vorticella, 5. Campanella.

Multiple branching is found less and less as time goes on, suggesting these branching points to be prime locations of detachments. As detachment shortens tufts, the denuded areas between the remaining tufts vary greatly in size, though they are fairly constant in beds at the same depth and at the same time. The basal cell or fragment of a cell of a detached filament in drift material may be fresh, deformed, or a sporangium.

Material, that has been detached early by carp rooting, often floats in longshore currents. The currents and filaments reach a point where they leave the island and descend to the bottom. Older detached material is generally submerged throughout its drifting existence. Some detached filaments get caught between rocks or are washed upon beaches, but most are dumped where currents play out over the bottom of mud accumulation. (Fig. 15). Filaments in living condition may continue to shift with currents for several weeks, but decomposition sets in within a day after mud coating or burial that accompanies storms. The cell contents of old filaments usually decompose first, but cell walls sometimes disappear before the contents do.

Cladophora is not found on rounded, polished pebbles, even after 3 weeks of calm, and apparently does not establish there. Surprisingly, large isolated tufts are occasionally found on sand bottom. However, these tufts are always attached to stable substrate within several inches below the sand surface. Bays underlaid by silted rock harbor tufts occasionally a yard long. However, coverage is shared with rooted angiosperms. Valisneria is most often associated. Myriophyllum, Ceratophyllum and Potamogetons are also common in this area.

Dark green filaments form where there is low light intensity on bluffs, deep water, and under sand. Growth on bluffs retains a fresh appearance compared with the robust, bushy, woolly, growth that may approach a canary yellow color on well lighted shelving. Long, streaming tufts may develop several yards apart on shelving. The edge of the bed in the deepest foot or so of water has slightly shorter and more sparse filaments than those of the upper part of the bed. The lower boundary of the bed is usually sharply delimited. Below this, coverage with short filaments of arrested growth is general, but more sparse. Occasionally, Cladophora patches of normal appearance are found below the beds. Many mollusks that inhabit partially silted rock carry filaments, but those offshore in mud are devoid of them.

The summer shoreline band of Cladophora fades at a depth of 0.5 to 1.0 foot. It is densely established below this for another half foot but filament stubs are covered with Gongrosira. Cells of these shoreline Cladophora filaments are not quite like any described so far. Often, they are only twice as long as broad. They develop slightly curved and clubshaped, making a graceful branching system. Sporulation involves many cells, leaving cleared patches in the mass. Gray-white patches with shrivelled contents are also found above the waterline. Cell walls do not layer as thickly as the walls of the spring crop did.

Summer filaments persist and in autumn the whole shoreline may clear following sporulation. Below the shoreline, the autumn crop proceeds as did the spring crop except cell wall layering is often not attained in cold water.

All these growth forms are considered to be Cladophora glomerata.

METHODS

Details of methods are included in Kishler (1967).

A new sampling perimeter for Cladophora on the rock surface has been used, beginning in 1968. The device was made from roller chain of one half inch to a link. Alternate links were cut along one side and the chain bent sideways into a near circle in an effort to obtain lateral rigidity with free vertical flexibility. The area enclosed was 235.0 sq. cm. or 36.6 sq. inches and a total range of areas could be made to vary one half sq. inch by forcefully distorting the perimeter. This "sampler" was more rugged than the square-foot bicycle chain used previously and was easier to handle on submerged rock. The circular perimeter minimized the perimeter to sampled area ratio, and the smaller area sampled is felt to be sufficient for Cladophora.

Underwater visibility on the island shoals is generally limited to 6 - 10 feet. However, the stations of Hatchery Intake and Village Intake were taken to be quite representative of the west shore and the southeast shore respectively after 28 South Bass Island stations were sampled during 1965.

The number of samples taken at each of the two stations during 1965 was 17, 1966--12, 1967--5, 1968--9, 1969--8, 1970--11, and 1971--7. A sample consisted of the following data: Two different subsamples (sometimes only one) were dried and weighed from chain sampler areas; duplicates (at the same water depth) were not taken after 1966. Usually three or four grab samples (extremes--one to eight) were taken from different depths for microscopic and tuft-bulk comparisons with material from the chain sampler. Percent coverage was estimated during the rare instances when the downward extension of growth was not complete, and after detachment began. Depths (∓ 0.1 foot) of subsamples and coverage estimates were recorded. The lake level at the time of sampling was also recorded from the G.S.O. chart at the Fish Hatchery.

Great Lakes Chart No. 364 was used to estimate underwater acreage by planimeter. Low water datum 570.5 (1935) was used in the chart and subsequently throughout this paper. This corresponds to 568.6' (IGLD, 1955).

A hooka diving rig purchased for the project permitted more observation of attached and drifted material than had been made previously by free diving.

Cladophora at the west shore station was removed from rocks several inches below the water line one half to one hour before the photosynthesis tests, unless noted otherwise in Tables 1 to X111. BOD bottles containing the Cladophora and approximately 295 ml lake water were placed in a quarter inch mesh wire basket which was suspended at the lake surface from a floating dock. The bottles were subject to wave motion. When more than one depth was involved bottles were hung from a buoy, and light was measured with a YSI oxygen-temperature meter and/or a laboratory or field model Beckman pH meter. Verduin's (1950) method was used to convert pH changes to CO_2 changes. Algal material was weighed after the tests when it no longer lost moisture to blotting paper.

Aerial photographs were taken by Mr. Cooper, Department of Photography, The Ohio State University, Columbus. During the short three hours between his alert and his photographing, waves had developed and the area became overcast with haze. This precluded the possibility of the photographs penetrating through the water to the Cladophora's lower boundary.

Detached Cladophora was picked up on an 8 inch diameter sphere of barbed wire that was dragged across the lake bottom in line with a drifting boat. The locations of samplings were determined by comparing the time of sampling with the time of reading of sextant angles at the beginning and at the end of a drift course. Landmarks were used as targets for horizontal sextant angles, and fixes were determined with the aid of a three-arm protractor on the Put-in-Bay quadrangle. If the speed or direction of boat drift was felt to have changed during its course a third fix was determined. Sampling times were less than a minute and those samples where Cladophora was present are plotted in Fig. 15.

ROLES OF CLADOPHORA IN WESTERN LAKE ERIE

Of all the habitats of western Lake Erie, the rocky shoals of high mechanical energy and Cladophora have changed the least. Elsewhere, where considerable awareness was once necessary to find one's way through the tall vegetation stalks of sheltered bays, any drunk can now power his way to the marina. The barren bottom off barrier beaches hardly hints of former cover there. The once rich bottom plain is sludge in darkness. The wave-refracted light pattern, that rhythmically sweeps through the water, now fades out on the submerged rock slope.

A prized consumer on the shoals--smallmouth bass--is still snapping up stray crayfish; although many former visitors to the shoals--muskellunge and diving squaw ducks--are forgotten. Most community arrangements are still unknown, but a top community asset is certain: the surface area and cover of Cladophora. Some 10^{10} miles, or 10^{-3} light years, of filaments grow under 7 square miles of cover around the Ohio islands. The living patterns on an inch of filament surface is briefly touched in this report.

Effective water basin management requires inventory of the water's biota. Forms that are living free in the water have not been estimated within an order of 10 or more with credence. However, Cladophora offers unique inventory possibilities for a major organism. First place accuracy is attainable with the aid of aerial photography, color or infrared. Films were used in the present study, but with less than ideal results as they were secured during air and lake conditions too poor to sense the lower boundary of the algal bed. Cladophora's tendency towards complete coverage and uniform stands permit workable ground control sampling.

Elements are concentrated in fresh Cladophora from lake water, approximately 30,000 times for N to 100 times for Na. The order of concentration of measured cations is N P K Mn An Fe Mo Ba Cu B Co Ca Sr Si Mg Al Na (Table 3). Cation levels are similar to spectrograph plant standards except for low Na and excessive Fe and Al in Cladophora. Heavy metal accumulations are assumed to be quite high in the absence of local measurements. Gileva (1962) suggests Cladophora for the removal of radioactive heavy metals from the water. Meeks (1966) found Cladophora adjacent to Sandusky Bay to be the most effective accumulator of DDT.

Even a total Cladophora harvest would have an unmeasureable effect on the annual nutrient budget of the basin. However, shoal water that moves rapidly offshoal is effectively desalted by seasonal Cladophora uptake.

There is little addition of N, P, and K after the shift in Cladophora metabolism to cell wall layering in older material and this is probably largely in its epiphytes. However, Hanic and Craigil (1969) found an outer protein-rich cuticular region in Cladophora rupestris. Cu, B, and Na increase proportionally with dry weight and there is an exaggerated increase in other micronutrients, especially the N metabolism linked molybdenum. Vacuole pressures are inferred to increase from the distortion of cells and this seems a probable location of much salt concentration. Encrustations make Ca the greatest cation component in old material. Diatom Si becomes notable.

Protein synthesis ceases in warm water except under the high light at shoreline. While nitrogen levels in the lake water decrease during the summer (Ogawa and Carr, 1969), the shift to cell wall layering seems more in the nature of Cladophora than in the chemical environment. The alga's peculiar seasonal distribution patterns and morphologies suggest that they are controlled by isozymes for protein synthesis functioning in two temperature ranges. A high photosynthesis to respiration ratio seems required for protein synthesis and lower ratios lead to detached akinetes, which are not functional in Lake Erie.

Respiration rates have a Q10 of 2 to 2.5 in Lake Erie's temperature range. from freezing up to about 80^0 F. Photosynthesis rates peaked within 58^0- 69^0F under medium light intensity with the temperature of maximal rates shifted towards the alga's acclimated temperature. Manning (1938) discovered that photosynthesis in Cladophora, contrary to most algae, increases up to the brightest sunlight conditions. Photosynthesis may always be limited by the amount of light penetrating the thick cell walls to chloroplasts. While robust, dark green filaments may slightly out-perform robust, light green filaments; flimsy and pale filaments vastly out-perform both of them on a bulk basis. The factor of light at the chloroplasts dwarfed other conditions influencing photosynthesis in Lake Erie Cladophora, and photosynthesis data without this parameter is not felt to be mathematically comparable.

By using an assimilatory quotient of 0.85 (Benoit, 1964) it is calculated that a gram dry weight of algal material produces a liter of oxygen by photosynthesis. This would total 14,000 tons of dissolved oxygen produced with the 1966 Cladophora crops around the Ohio islands. It would equal ten ppm O_2 in one million acre feet of water. A similar amount of oxygen is consumed by autorespiration and afterwards by decomposition after detached material drifts below its photic zone. Oxygen produced on the shoals during cooler months is not critical as is oxygen consumed on the bottom plain during a few warm days of intensive decomposition if the lake stratifies.

Excretion products off the Cladophora community could bear investigation in connection with the early summer planktonic streamers and relatively clear waters of that season. Also, overwintering filaments liberate oxygen, but do not grow, and are a potential source of excretion products.

Many people see attached Cladophora on shorelines during the summer. This growth barely enters annual production totals, but it is the only summer harbor in rocky habitats for many small living forms. It should be considered of tremendous importance for this function in the absence of contradictory data. Leeches often dominate the rubble covered habitat after Cladophora detachment. Summertime growth attaches to any solid substrate in less polluted and more exposed areas, but piling and rotting does not follow such growth. Many boatmen, who have crashed into docks after cleaning Cladophora off the hulls, attest to the drag it adds to boats.

A cubic foot of rock was estimated to dislodge yearly along 10 to 100 feet of shoreline at the west shore station, with high rates during high water. Cladophora may hasten erosion by etching rock crevasses.

The fraction of detached Cladophora that rots on beaches is minute for consideration of lake energetics, but it is the part that reaches our collective senses. Beaches on South Bass Island fall into three categories as to piling and rotting time. 1. Fleeting, minute amounts on West Shore Bluffs; 2. Less than annual windrows that may stay longer than a week, and with time enough to emit headline odors, on Southeast Shore Shelving; 3. Stretches totalling several hundred yards always present at Buckeye

Point and the north side of Monument Bay. These categories apply to the spring crop, which detaches during June and July. The autumn crop, which detaches during December storms, or not until March ice-break, can pile on beach but has not been observed to rot there.

Windrows are piled by head-on waves and a slant of several degrees in wave direction usually cleans the beaches. Wind is the main objective determinant for collective opinions of Cladophora abundance. Low water levels extend possible piling by exposing more shelving beach. The duration of cold water after spring ice break may influence windrowing. Temperatures below 50^0 F favor Ulothrix in shallow water. Ulothrix quantities are not sufficient for piling and rotting.

An extended Cladophora growing season due to low early summer temperatures deepens its lower boundary, but drift from the deeper parts of beds does not accumulate on beaches. This is assumed from the extreme rareness of the late summer Plectonema on beaches. The deeper Plectonema zone is probably similar to the Cladophora zone in extent and the two overlap by several feet. Plectonema drift has been found in the central basin 15 miles from a possible solid substrate to which it attaches by entanglement.

Detached Cladophora has also been found this far from a possible attached source and seems more mobile than silt. However, a great share of drifted material remains offshore just beyond the edge of silt accumulation on the bottom. Upon detachment, longshore currents carry drift either beneath the water surface or off bottom. A solid train of drift four feet wide and a foot deep has been observed across the bottom off Limekiln Dock, south shore of South Bass Island. Surface drift has been seen to descend at boundaries between waters of different apparent clarities off Victory Point and off Lighthouse Point, west shore, South Bass Island. Cladophora drift on surface is seldom seen beyond longshore currents. This contrasts with Valisneria drift, which floats for an undertermined length of time and is often seen in open water throughout the summer and autumn. Cladophora buoyancy is dependent on adhering gas bubbles that are shaken loose by waves. This is fortunate for boating and shoreline interests as Valisneria affords enough lodging surface for dying blue-green algal blooms.

Southeast of Ballast Island is a large, natural "dumping grounds" where longshore currents off the north and east shores of South Bass Island play out after leaving shoals. Dragging operations indicate that fairly clean and living Cladophora may persist here for a month, shifting position somewhat from day to day. Eventually a storm coats or covers all the filaments and decomposition sets in by the following day. The drifted material in Fishery Bay was seen to be dense and in a foot-thick layer, but momentary. Water exchange is too rapid for a field to persist here until it rots.

Some approximation can be made of what average material consists at the time of detachment by comparing data on macroelements of those old samples with high ash contents with fresh material (Table 3). Dry weight samples with approximately 37% ash are typically 75% Cladophora and non-diatom epiphytes, 2% diatoms, 8% calcium carbonate deposits and 15% clay incorporated in cell walls.

Cladophora drift is more than accumulated nutrients, heavy metals and insecticides. Adherents and entanglements include porteinaceous blue-green epiphytes, calcium encrusted Gongrosira, carp eggs haloed with mold, mating gammarids, crystalline caddis houses, dolomite particles plucked with holdfasts, lodged silt, duck droppings, willow twigs, and fish hooks are among those sharing the predominantly cellulose vehicle to its terminus. Drift contributes towards a varied and poorly sorted soft bottom. Its adherents reflect on the time and place of its origin. Cladophora's fraction of annual biomass is minor compared with phytoplankton, but its contribution to the soft bottom is noteworthy.

Cladophora drift in fish nets is not regarded as a primary cause for the termination of the commercial season in June (Russell Shoal, personal communication). Even if an isolated approach is taken, it is difficult to prove the alga as detrimental to fishing. The possibility of night time oxygen depletion harming the spring spawns is greatly reduced by rapid water exchange. Its silt collecting and possible smothering season arrives after eggs, except carp-goldfish, have hatched. Filaments are rare in fish diet (Price, 1963), but the organisms dependent on its cover may now be irreplaceable as food for the small fish trophic level.

Black ducks (Trautman, 1947) and mallards feed extensively on Cladophora, and this is apparent on the less disturbed shores they visit as filaments are often but little changed after passing through their digestive tracts. This diet of accumulated heavy metal and pesticide potential should not be disregarded in explaining cases of extensive duck illness as during 1969.

During June and July western basin waters clear at the same time as attached filament accumulation of clay and silt. The clearing ends with blue-green algal blooms following filament decomposition. (Plankton populations, however, seem independent of the size of the Cladophora crop.) The volume of silt that coats attached filaments sometimes becomes many times the volume of the filaments. The two vegetation to one clay requirement for reducing turbidities that Irwin and Stephenson (1950) used would seem a gross understatement to apply to the Cladophora community and its decomposition products.

Bryozoans deserve special attention as filterers of Lake Erie water. Most American freshwater species are present in the vicinity of Put-in-Bay, some abundantly so during late summer. Masses of the diet-colored Lophopodella carteri var. typica (Hyatt) Rousselet are imperceptibly motile and occasionally coat entire visible areas of solid substrate, especially angiosperm vegetation. Rogick (1934) found that cultures "came to life" upon adding waters ambered with rotting vegetation (rotting Cladophora qualifies). It would appear that the population potential of Lophopodella has paralleled the fortunes of aquatic vegetation for the reasons of establishment and food.

Rogick counted 15 and 26 peristaltic contractions per pellet production in these voracious feeders. Large phytoplankters--Aphanizomenon, Coscinodiscus--are included but appear unaltered in pellets.

Pellets sink, remain cohesive " for at least a day ", and are possibly an ideal food for numerous species of small bottom feeders.

Polypides occupy about a seventh of the total area of confluent colonies. Pellet volume is almost equivalent to a normal standing crop of phytoplankton in the column of western Lake Erie water above it. One can appreciate the chances of late summer algal blooms over a vegetated bottom with the initial pulse of the plankton passing frequently through lophophores, and compare with the present blooms over a liquid bottom.

" POLLUTION IS A NON-CONTROVERSIAL TOPIC "

All Lake Erie beaches should be purified from lesser organisms, like Coney Island is. In our awesome task to set our women and ungrateful progeny on a weedless launching pad to heaven, an inventory should give us a boost--we've gotten away with a lot.

Nutrients no longer thicken and discolor tributaries, or if the water is tinted with nutrients, it's effectively masked by turbidifying suspensions. Swamps and tall prairies, where one was in danger of getting lost from the eminent domain, are as beyond memory as the regions' reputation for fevers. This seems to have disappeared the day the public ditch law passed in 1859, paving all ways to Goodies Amalgamated. Tens of thousands of acres of wild rice (now a bargain at $ 6 a pound) no longer bury filamentous algae on beaches, or mayflies smother fields along the shore. We're spared the scene of storms tossing large fish on shore and the devouring of them by eagles. Objects with large biochemical oxygen demands, such as sturgeon, are quite under control and do not interfere with power boating on the tributaries. We no longer have to put up with deer swimming between the islands. The sight of ducks breasting down stalks of wild rice to feed on the grain does not have to be endured. Bird flights no longer darken the skies. We aren't kept awake by their yaking in the marshes or by otters sliding down river banks. While practically no one ever looks at the bottom of the western basin we can rest assured that there is no longer any large area of black mud. In fact, in those few, fearful hours the bottom plain can be seen, it looks as barren as deserts of the holy land. The thought of light sensitive organisms there now makes us chuckle. The top qualification for living there now is the ability to withstand frequent sludge burial; what more could we want? Our improved quality of life will be appreciated by comparing the humor of today's spokesmen with Chief Chano's requests for American sanity, which we finally got around to after 8 years.

But enough of this happy progress report and on to the serious business of justifying our existence by pushing old standards in new ways. Early developers never intended for us to learn from their struggles. They intended for us to invent new frontiers to clean up. Fortunately, the natural checks on algae are well disposed so algae give us a rallying point for spurting past this balance of nature Mother Goose rhyme, and replacing sessile filter feeders with professionals who stand tall. We're on the right track for wiping out algae and other monsters by declaring war on phosphorous, that is, specifically, simply-protoplasm. Phosphorous "hailstorms" from past flights of passenger pigeons, estimated over 200 miles long and totally eclipsing the sun were not sufficient to support sprigs of algae. Already the daily food consumption of the people of North America may have equalled that of an entire flock of the extinct birds. Since pigeons were probably thousands of times more discrete with their droppings, the need for centralized restraint of total organic matter is paramount for saving the lake. That we'll have to make the water much poorer in nutrients than Lake Superior was off St. Ignace Island a century ago in order to starve Cladophora should not deter us for a minute. For in recent years, we're losing control of keeping the lake muddy and algae in the dark. The control seems to be returning to water clarifying organic flocs which we must stamp out quickly.

The situation is not as serious as when we arrived on the savage scene and open water was top quality for so many species, including us, and we ruled it not. Remember, lakes are like children: flush in organic matter and after a while the same matter is flushed on; so flush fast. We won't spend one billion more than is necessary, but this recent affront of water clarity and more algae demands our concerted action, and the war on protoplasm may have to be augmented with encouraged oil spills. But it is inappropriate to play this ace in the hole at this time. However, now is the time to stop boondoggling a county-ditch, a highway project at a time and begin improving the Rapids of the Maumee River by channeling them out to give running water a good bite of the ground of the whole Maumee watershed. For those whose heart is set on destroying the Cladophora community by starvation, it is recommended they take a course in elementary Botany to grasp the effect of continuous shading on chlorophyll, and compare with the fun of "nutrient starvation", Cladophora cells won't even pop in distilled water anyway.

This is the situation: One senses that a Lake Erie program that sells to us is for a regression to pristine and de-bugged water and once again being "fresh water fish capital of the world." One assumes the obligation of putting in a word for us at the next appointment with one's fairy godmother.

Meanwhile, the snug world of non-integrated benefit cost analyses indicates that an inspired turbid and lifeless lake is in order. Rapid runoff structures and channel improvements drain the watershed quickly of water, soil and whatever we want flushed away. Fines begin to be deposited on the wane of the flush, and breeding grounds for the lake's biota are shrunk to the lake itself. Here, photic zones and breeding grounds are detracted further by submitting to suspensoid bargains from fixed-shore industry, agriculture, construction and harbor dredging. High water not only greatly profits power plants and navigation, but greatly adds solids from shore. A huge program for the elimination of an "allothonous" nutrient may eventually disfavor the more protein dependent biota and lake clearing by flocculation. Entrenched treatment for tolerable water and profitable beaches are envisioned. Politicians are elected to say "it's all their fault." Armchair flights on pollution provides an imaginary safety valve for the whole machine with aggressive organizations at the accelerator. Expansion policy accompanies as a "side effect".

Maybe half of Lake Erie's species have met our test by perishing. That's not as good as in the little squares of the lake's watershed where we have species dwarfed and well in their place, such as walnut trees, English bluegrass, corn, elephants and savages. Extinct species are no lesson, as we know how to avoid or migrate or expand to unfamiliar situations in our world of limitless opportunity. As always, spurious protoplasm will be pitifully defended by these quaint people with narrow horizons, who feel it human nature to have bond with the land. They should compete with fertilized southern ponds for carp mongering while we're cleaning up. They should be ashamed of fretting over trivia and should initiate a megopolis sprawled over a man-made barren landscape. Personal views have no place in civilized endeavors. Strange contact with nature saps the regulation of nurture that a dominating people must have for our divine image. Don't worry about distinguishing between protoplasm that is spurious or in its place; that's where well-schooled promotors fit in.

Already our idols see the folly of mimicking Wildcats, Bears, Bison--among the first to be annihilated by technology in the Erie Basin. It seems unreal now that we'll come to recognize the regional champs of technology: the Algae, the Sludgeworms, the Cadavers. But our challenge promises an aria of performance. Who knows? After a century our departmental addiction to manipulating them may complement the Koryak's tragic love of the Greenland Right Whale.

Regional champs are big league to mere city champs, not just by ratio of the areas covered, but because the fruits and nothing but the fruits of urbanization are brought to everyone in the region regardless of one's stomach for it and decision to incorporate it. Try to turn off the mass media, this is Sludgeworm-Pea Soup country: those quickies that thrive on progress, the silent majority raised to a pinnacle by default. The opportunity to say periodically "we cleaned up on them, too" needs a crusade, and that's the sports picture for now.

Obviously, the wiping out of fertile areas, perfectly, is the life style for all of us. It makes for a situation in which incompetent dreamers are weeded out by frying drug adventures. Besides, slums are more relevant comparison posts than undisturbed areas for justifying the drudgery of fitting round people into square niches, and for receiving the outpour of our liberal hearts. What more popular and profitable way to treat the deferred pains of population pressure than by mission: sterilize the earth! With supernatural visions, who needs to be accepted by nature? So support central's drive to wither the natural channels of unruly competition into a museum experience. We did not get to be number one spectre of the empires by listening to alarmed preservationists, and our margin on inspiration is secure.

CONCLUSIONS

Sensitivity to Lake Erie is practically dead. We're well trained to think about streams and lakes in terms of their impurity. Ivory soap seems to have set the standard for the expression of the degree of purity to the fourth significant figure, and a luxuriant technology has been pulled into the water field. We can now focus sharply on impurity to keep out of touch with the health of the aquatic environment.

A framework of stream and lake resiliency is more workable for consideration of our epidemic on the land and water. Influence peddlars would be capable of bombing resiliency senseless with a 'fountain of youth' campaign. Resiliency is a quality of mature, stable ecosystems. Resiliency had the power to turn around the natives of the Maumee watershed after their military escort to Kansas and had them straggle back to die by their stream. But this leap in thought from stream conditions to man's basic actions will be denied; it does not lend itself to laboratory experiments. So long as we're preoccupied with oneupmanship we can't fathom this understanding that was the bent of native Americans.

Cladophora and its intricately timed community are survivors from the mature ecosystem that was established in pre-settlement western Lake Erie more than a century ago. Abundant detritus from diffuse sources was an integral part of the ecosystem; continuously suspended mud was not. The organic wash that accompanied the retreat of barrier beaches was more than enough to precipitate the clay off eroding till bluffs. Winter and spring tributary issues were relatively clear and constant in flow. Darkened and thickened waters were debouched into the lake during the low flow season of late summer and autumn. However, decomposition products off swamps and prairies were assimilated and oxidated and water cleared over the hard substrate of the middle reaches of the Maumee River system. Sources of substantial re-enrichment were the lake margins, drowned river mouths and shoals. Emergent vegetation and occasionally inundated lake marshes totalled over one-third the area of open water in the western basin. There are suggestions that the open water was essentially underlain by submerged vegetation. These diverse nutrient feeds were converted in high quality Great Lake water to an abundance of life that we find incredible today.

Many of the nutrients were in organic forms that were incorporated directly into microorganisms and invertebrates, and initially bypassed Cladophora. However, the boundaries of Cladophora were determined by the extent of hard substrate in the clear water. Also, it is possible that filaments remained alive after summer detachment and drifted onto a vegetated soft bottom until autumnal coating by storm-suspended particles.

The practically complete conversion of the Black Swamp into row cropped fields was accomplished with desperation and disregard of the ecosystem. Negatively charged tributary mud that was too much to be flocculated by humic acids accompanied the conversion. Most of the mud was of glacial lake clay and silt and remained suspended during the spring season until flushed through the active waters of the wastern basin. The bottom became shaded and its photic zone shrank to the margins along the shoreline. This is where the public detects the green filaments and the collective opinion is that there is more now than ever. This is expensively held in the absence of former measurements of Cladophora abundance. The alleged algal increase is attributed to greater nutrient injection via channel vision, blocking out the ramified nature of algal abundance; nutrients are held on suspensoids passing next to the algae we see at the surf. A lush strip of algae takes less total fertilizer than an extensive aquatic meadow. The broad base for algal competition, inhibition, and consumption is destroyed. Nutrient input into western Lake Erie is not a first order limited to Cladophora; it probably never has been. Satisfaction in our treatment of algae will be limited to the dollar so long as algae are limited to spot studies designed for a bad press.

Evidently, cleaning up a house sink is good business so cleaning up a Great Lake is good big business. Perfectionism in assaulting the environmental establishment is traditionally trained for and rewarded. The starving of Cladophora is a part of the best speculation today as the burning of 9 foot diameter black walnut trees was a part of the best speculation a century ago following the first period of city planning. However, relative immortality has been achieved and rocky shoals are not always so awesome as the Black Swamp was. (When was the last time you were under a lofty, dark forest canopy extending thousands of square miles and amongst 4-10 foot diameter trunks so compacted that you were lost if you wandered 15 yards from the path?) New technology becomes necessary, crudely, as when taconite followed hematite mining - partly because we haven't completely found a way to dice the lake for the attack. The influence industry is contracted and, presto: the reputation of Cladophora is made by lumping it with industrial smog and throw-away litter; not to mention its ever-present threat of strangling bathing beauties. If whitefish, one of the world's prize protein foods, were surviving, it would be joined with Cladophora as a polluter. Pioneers scarcely noticed anything that storms had tossed on the beach other than those big smelly fish that Indians had failed to pick up. Indeed, less of the algal filaments would be expected to have been driven up from the deeper growths in clearer water.

Assuming that Cladophora community could be put in its place, presumably exterminated to perfection, what would take up pesticides, radioactivity, and heavy metals from the water supply? Where would be the source of fish food in the western basin, other than from marinas and runoff injections? Further, unrealistically assuming no change in plankton, it would mean another reduction in bound nutrients, species diversity, productivity and water clarity; then plankton composition. If this basin that has always been identified by its "astonishing fertility" is finally written off as a quality primary producer and its watershed written in as megalopolis, whose territory do we turn to for more dependence and aggression? What comes after mob drunkenness as the main urban contribution to the islands above the waterline?

It is suggested here that the present changes in Lake Erie are largely chronic reactions to the shock of our early developments. While the urban developments of today's high energy society are a more sophisticated source of pollutants, the ecosystem as a whole has been held down to a hostile pioneer stage for a century. A reality more in touch than reflex faith in glamor pollution companies and purge of scape goats is necessary if further development of a detrimental region is to be effectively contended. To say that the recent big change in Lake Erie is due entirely to recent technological and population explosions, that we with all our electronic slaves have more effect on landscape pornography and lake dis-productiveness than did the few pioneers with survey stakes, an ax, a shovel, and a plow, is a milking charge for advanced narcism. However, the general effects of today's culture will not be known for generations.

Lake Erie isn't dead; its back is broken and we're figuring more efficient ways to overload it. A muddied, fluid-bottomed, dis-productive Lake Erie, that is undesirably reactive to minor clearing, is getting easily overwhelmed controls by expanding organizations, and sentences reflection that environmental catastrophe is subordinate during the existence of a profiteering culture. The alternate, more difficult interest is in the requirements for a natively clear, complex, and resilient lake.

RECOMMENDATION

Lake Erie isn't free to heal with 100,000 people of our hydraulic practices in its watershed. We've passed 10,000,000. Our best hope now is to look up and learn from successful parasites and ease our destruction of our host. Although our concentrating of organic matter festers our host at strategic points, it is the universal megatonage of "non-biodegradable" but reactive mud that saps the productive energy of the aquatic system.

The time unit for expecting changes in Lake Erie is decades and reliance on extravagant crash programs connote a "will to fail"; so do no programs. A preventive agency for aquatic resiliency is needed with a primary objective of limiting mud flows below that of biodegradable matter. Integrity demands that the agency be concerned only with the smallest unit that affects the entire lake. This seems to be in the "key area" of the western basin and its watershed. Since the agency would have to play against a stacked deck, it would need limited power to give positive or negative recognition of educational, technical, economic and social natures to individuals and organizations, public and private, according to their aquatic practices.

We can ill-afford to lose the basic biotic energy in the lake system, but an insurrection against the cultural source of mud is unthinkable. Before storm water off our rapid runoff structures--roofs, roads, ditches, frozen plowed fields, etc.--collects into channels of permanent streams, shock absorption is needed. Areas would serve as mud sinks off small watershed and prevent flows of erosional proportions off channels.

Quickest results could come from replacing the general field furrows, which divert water straight to the nearest ditch with furrows that descend very gradually from contour lines and lead into woodlots for water retention until flood peaks pass. Woodlots remain in nearly all sections of the watershed, but the slope may not be. Most woodlots have descended from swamp forests, and are generally limited in growth by drought today. However, excessive flooding may lead into problems of silting, Fusarium wilt and wildlife habitat destruction. Land bank fields and highway borrow pits may have further use for temporary water retention.

If these possibilities were exhausted there is still use for buffer areas where top soil is removed down to most advantageous elevations for temporary water storage. If these areas were to be at tips of permanent streams, there would be one farm sized unit in fifteen square miles or so. A series of zones may be required in a buffer area to translate seasonal mud flows into more uniform flows of quality water. The perimeter, which receives the widest fluctuation of the muddiest water levels, might best accomodate floating vegetation mats--exotic as they may sound, with maximized nutrient harvest off the mats. Occasionally inundated woods may follow with mud removal dependent on floor litter. A zone of good marshland may require that water fluctuations be held below two feet during the growing season. A permanent pond of sand filtered water may make the best final water delivery. Separating the zones would be removal dirt. This doesn't have to be left in regimented dumps, but may be shaped into, say, modified crescent hills that shield desired areas from northwest blows and funnel through southwest breezes.

It would be mandatory to find neighboring fields to where accumulated mud could be periodically removed, perhaps as hydraulically built terraces. Further investigation would be desired to find the plant and animal communities that would do best. Many of the species that have been eliminated from the region would be top candidates.

It might be desirable for organizations to develop buffer areas near towns. Public areas are rare where one is free to step off the side (of the road) walk without qualifications. Private developers will note that natural zoning would be assured to home builders.

Towns are generally located on permanent streams and town runoffs need special considerations. The possibilities of using flood plains for storage have become eliminated as flood peaks have steepened over the decades. The towns that are located along the abandoned canal might be permitted to run storm waters into it. It could be made desirable for quarries to store storm waters temporarily. Where stream bottoms haven't been dug out, banks have been cleared permitting erosion to broaden channels while deposition buries the original bottom. Re-establishment of firm bottoms and banks are needed for stream recovery.

Areas of water retention may enhance ground water recharge from soil percolation. Selected recharge wells may lead to more attractive and immediate underground storage if quality is assured.

If large mud loads were eliminated from the western basin, we could firm the possibilities of a stabilized tilth on the soft bottom. One feature of a solid bottom is that it is the base for algal control. The chances of repossessing a solid bottom may be as poor as that of reverting the Babylonian deserts back into gardens. Or sufficient tilth for productive and quality waters may result from increasing fertilization. What limnologist, who has first hand information on Lake Erie, could say?

Note that we were supposed to have chased the last effective preventive agency for aquatic resiliency from the basin to Kansas in 1838, when early, more modest developers planned a city reaching from Toledo to Fort Wayne. However, many escaped to nearby Canadian Walpole Island, Lake St. Clair, where their descendants wait their mercurial deliverance (Bauman, 1949).

Appendix A - Early Photographs of Cladophora

Postcards showing Cladophora circa 1906.

Gibraltar, North Side, Put-in-Bay, Ohio (color). The Hugh C. Leighton Co. mfgrs. Portland, Me. Printed Frankfort, Germany. No. 4951.

Lost Ballast Isl. and the Steamer "Arrow", Put-in-Bay, Ohio (color) A40287. Published by H.A. Herbster, Put-in-Bay, Ohio. No. 13. Printed in Germany.

East Side Shoals, Put-in-Bay, Ohio. No. 28. Published by H.A. Herbster and Co.

West Side Bluffs, Put-in-Bay, Ohio. No. 18. Copyright by H.A. Herbster. 1906 Printed in Germany.

Victory Park, Victory Bluff, Put-in-Bay, Ohio. Copyright by H.A. Herbster and Co. 1906.

Wehrle's Ball Room, Middle Bass Isl., near Put-in-Bay, Ohio (color). Published by Alexander Mfgr. Co., Sandusky, Ohio. No. 44. Printed in Germany.

The Old Limekiln, Put-in-Bay, Ohio. (Handcolor). Photographed and Published by H.A. Herbster. Impr. Reunies, Nancy, France.

Jay Cooke Photograph Collection. The Ohio Historical Society Library, Columbus.

These photographs were taken between 1865 and 1907, but not dated.

Some photographs were taken before there was a boat house on Gibraltar Island which is shown in a photograph of Put-in-Bay in 1872 by Richard G. Wendt, Sandusky.

Photograph numbers showing Cladophora. 8, 34, 60, 105, 108, 109, 149, 150, 210, 213, 217, 236, 245, 263, 296, 298, 304, 323, 329, 336, 345, 351, 358, 359, 362, 375, 385, 389, 392, 395, 403, 414, 418, 420, 427, 433, 435, 438, 444, 455, 460, 465, 470, 481, 482, 484, 488, 491, 493, 496, 499, 547, 575, 588, 591, 595, 611.

APPENDIX B

Figure 8. Locations of Collecting Stations at Island Region.

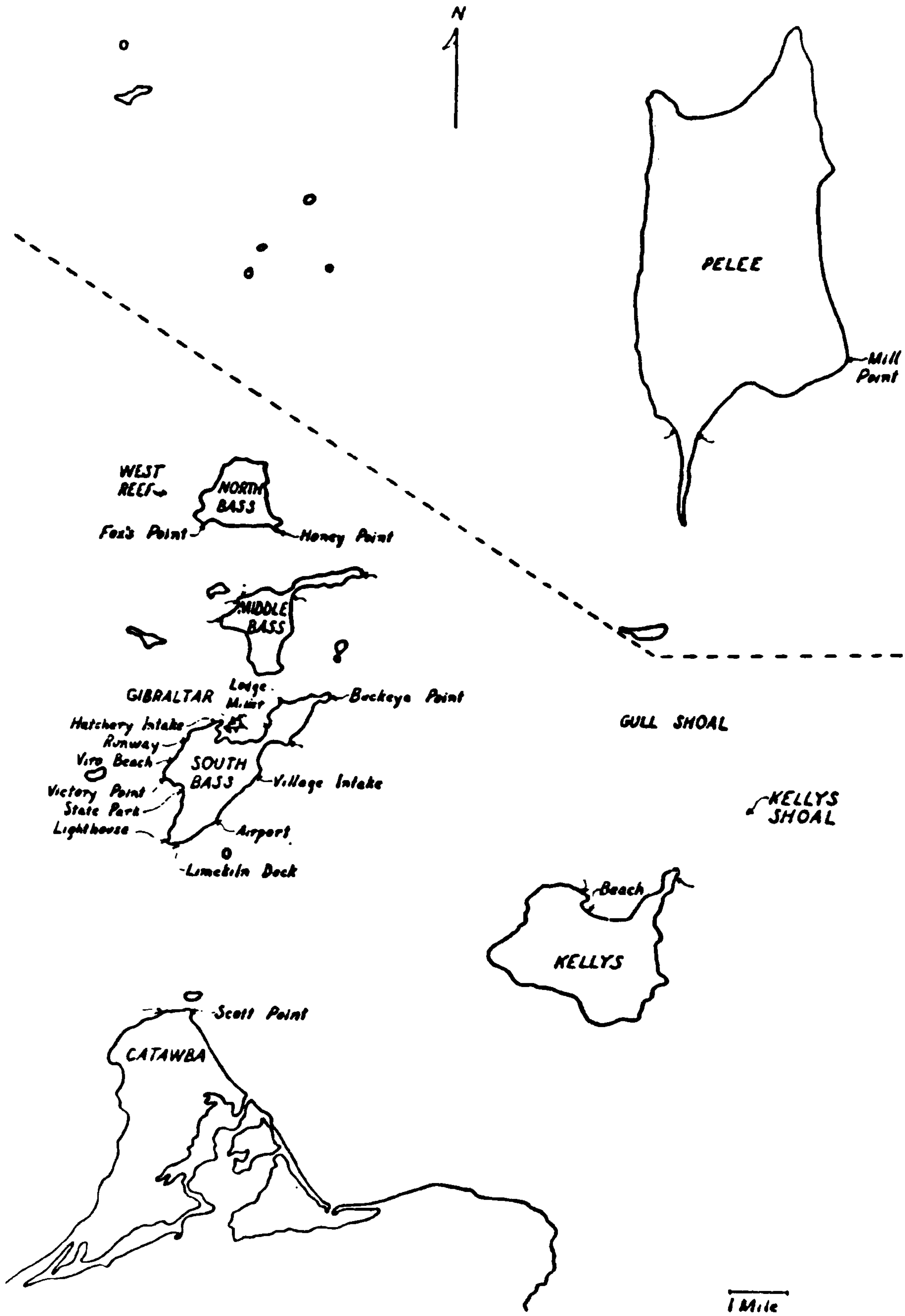


Table 1A. Lake Erie Water Temperatures in Degrees Fahrenheit Taken at 4:00 P.M., Put-in-Bay Hatchery. (Monthly Average)

	1965	1966	1967	1968	1969	1970	1971
January	33.5	33.7	33.3	33.0	33.1	33.1	33.0
February	33.7	33.7	33.1	33.8	33.7	34.3	33.2
March	33.9	37.3	34.2	35.2	35.5	34.6	34.7
April	40.2	45.9	47.1	49.2	45.8	44.6	44.3
May	58.7	55.8	54.6	57.0	57.3	58.6	56.0
June	68.0	69.3	68.6	67.7	64.3	68.7	68.8
July	74.5	76.8	73.3	73.4	73.1	73.5	75.3
August	73.5	74.1	73.0	76.3	75.7	76.6	73.7
September	69.0	69.6	67.3	70.1	69.3	71.4	70.9
October	57.4	55.2	54.7	59.5	58.0	59.2	63.3
November	46.5	43.9	42.2	45.6	44.0	46.9	49.2
December	37.2	35.9	35.7	34.9	33.7	35.9	38.6

Table 1B. Duration of Temperatures 50 - 65^{0}F, Put-in-Bay

	1965	1966	1967	1968	1969	1970	1971
Spring	May 4- Jun 1	May 1- Jun 13	Apr 27- Jun 9	Apr. 17- Jun 7	Apr 27- Jun 24	Apr 26- Jun 6	May 3- Jun 5
Autumn	Sep 28- Nov 7	Sep 24- Nov 1	Sep 24- Nov 3	Oct 4- Nov 7	Sep 25- Oct 28	Oct 2- Nov 14	Oct 8- Nov 9

Tables 1A and 1B adapted from daily records of the Ohio Dept. Nat. Res., Div. Wildlife, Sandusky, Ohio.

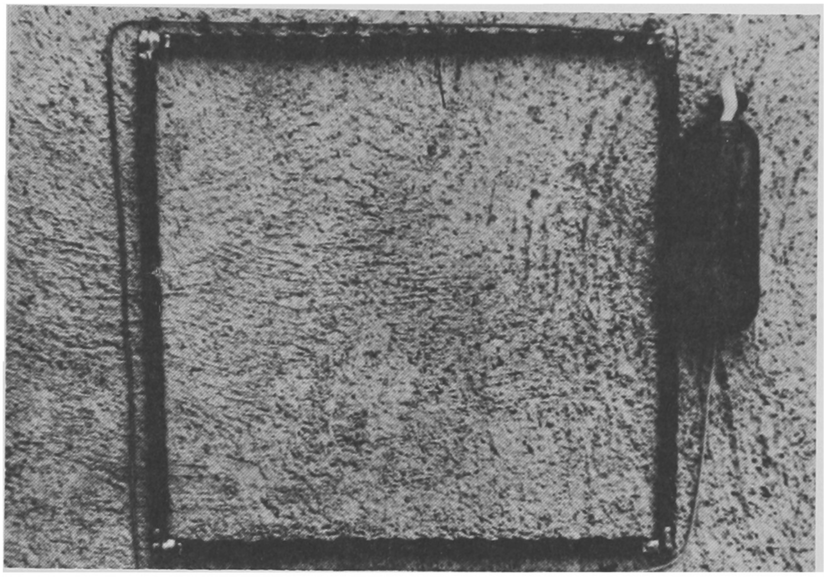
Table 2. Suspended Sediment in the Maumee River at Waterville, Ohio (Thousands of Tons per Month).

	1964-1965	1965-1966	1966-1967	1967-1968	1968-1969	1969-1970	1970-1971
October	1	20	1	1	1	6	2
November	1	2	103	6	4	125	5
December	1	47	694	730	173	3	23
January	34	53	4	104	382	5	2
February	326	34	101	199	196	82	248
March	211	28	225	72	24	124	115
April	338	25	110	182	198	361	7
May	14	111	131	355	108	343	96
June	2	2	3	104	51	14	43
July	2	40	2	15	53	25	3
August	1	1	2	12	3	6	1
September	3	1	1	1	3	2	2
annual total	930	363	1376	1783	1194	1096	548

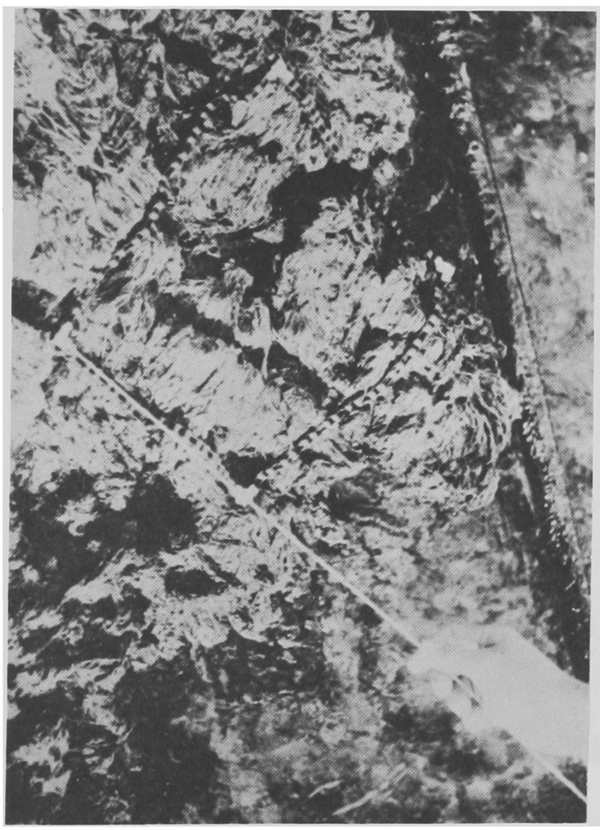
Adapted from U. S. Geological Survey, 1971 provisional records, subject to revision.

Figure 9. Photographs of Chain Samplers. a. Detail b. in place on rocks c. Circular type.

a.

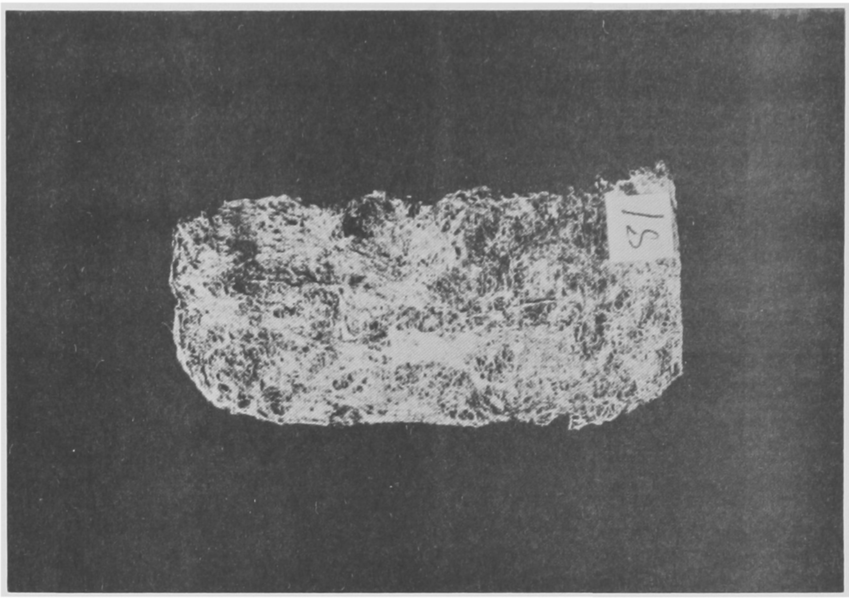


b.



c.

Figure 10. Photographs of dried <u>Cladophora</u> Samples.



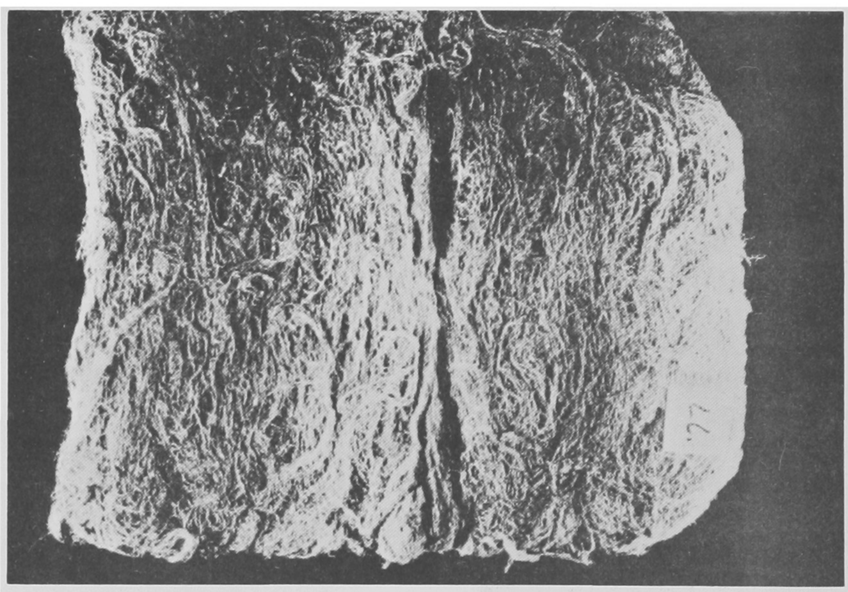
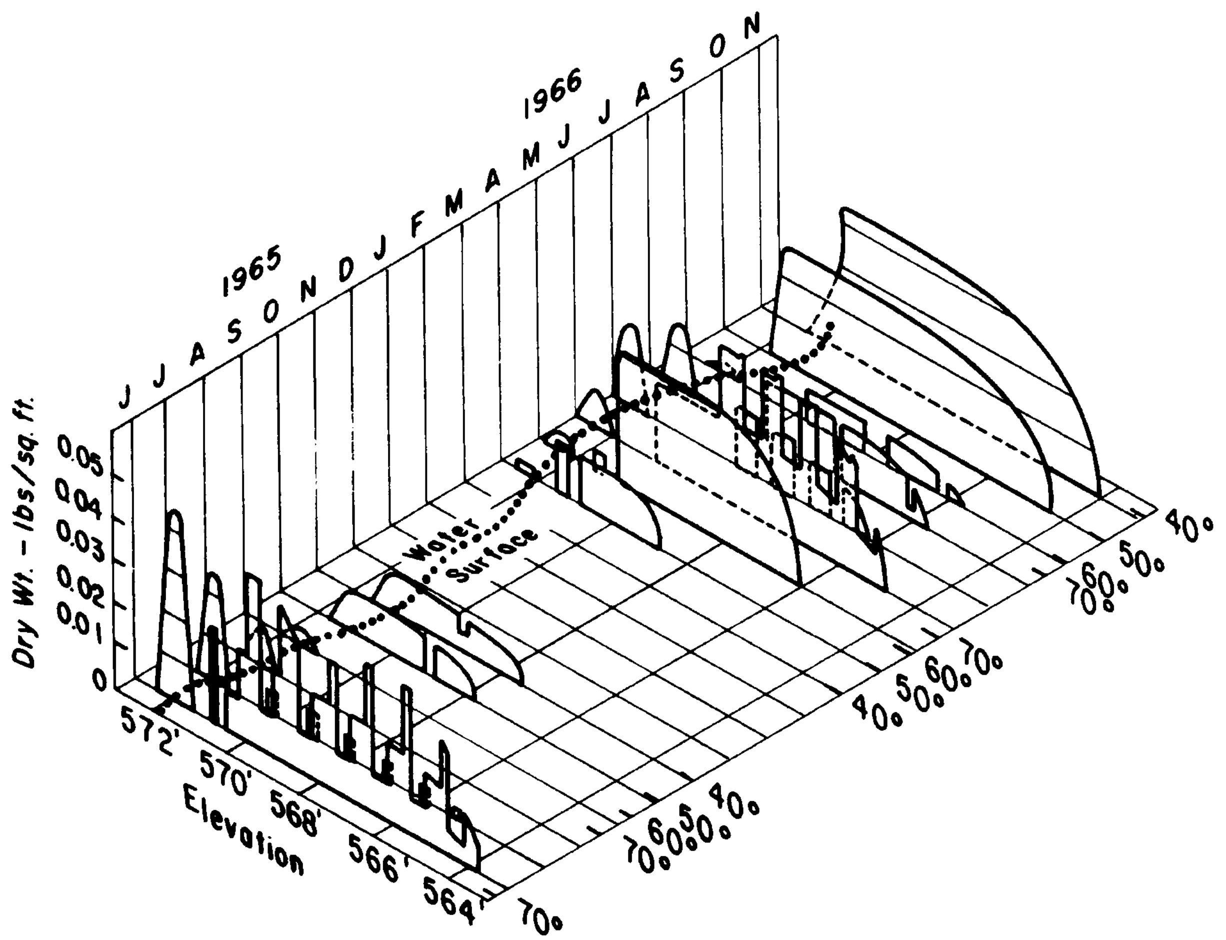


Figure 11. Monthly Dry Wt. Production of Cladophora at Hatchery Intake. N.



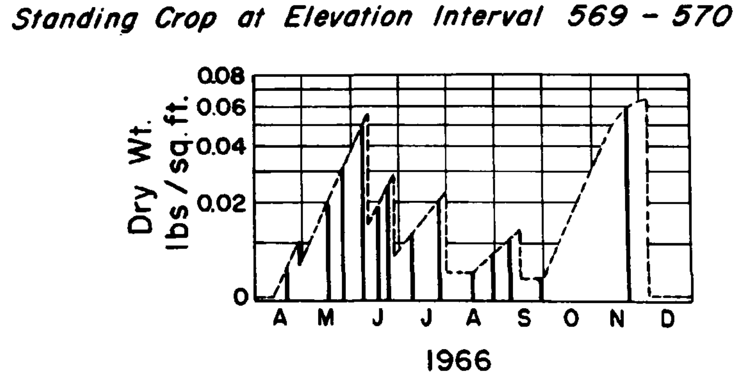
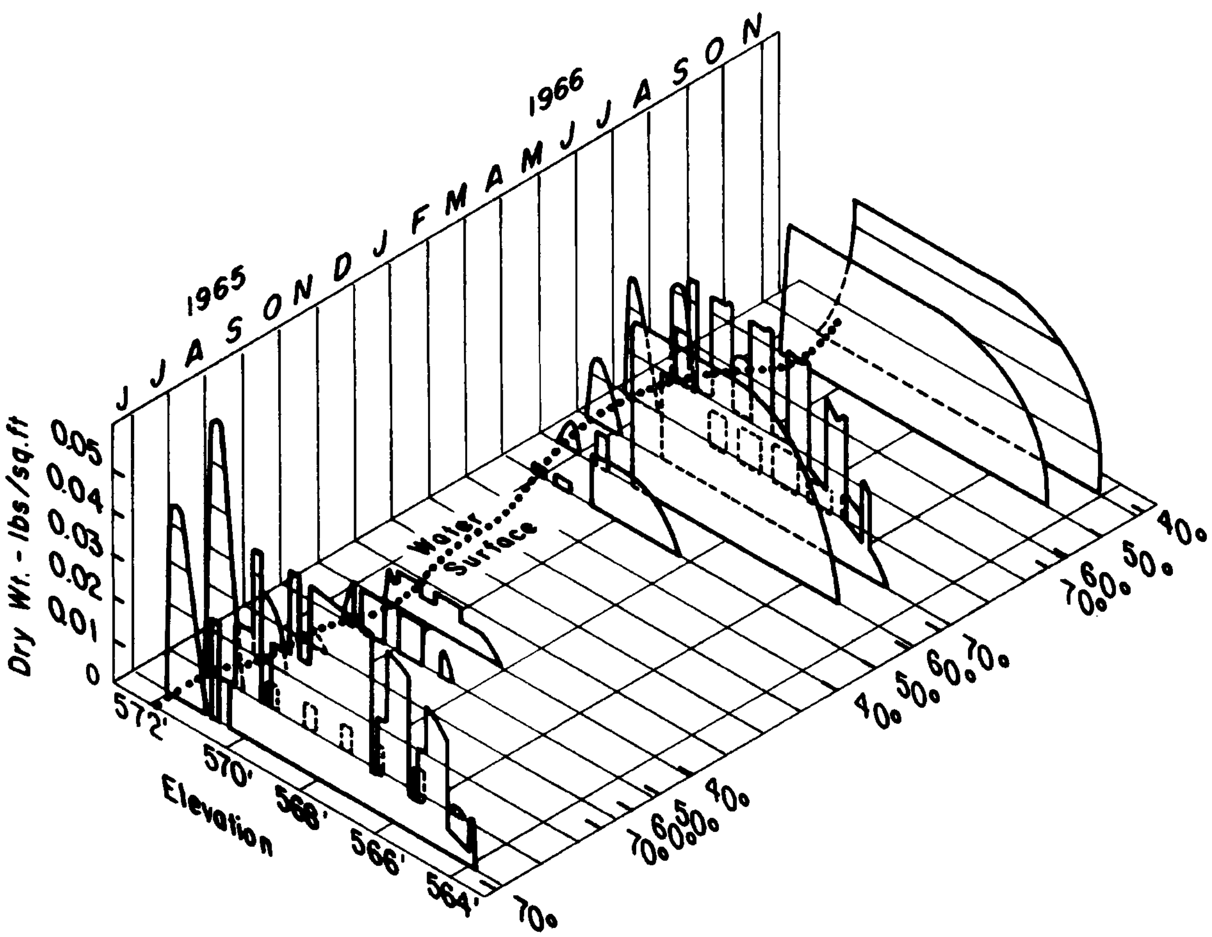


Figure 12. Monthly Dry Wt. Production of <u>Cladophora</u> at Village Intake. N.



Standing Crop at Elevation Interval 569 - 570

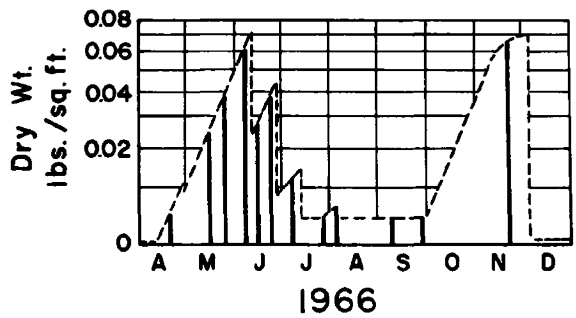


Figure 13. Seasonal Dry Wt. Production of Cladophora at Hatchery Intake.

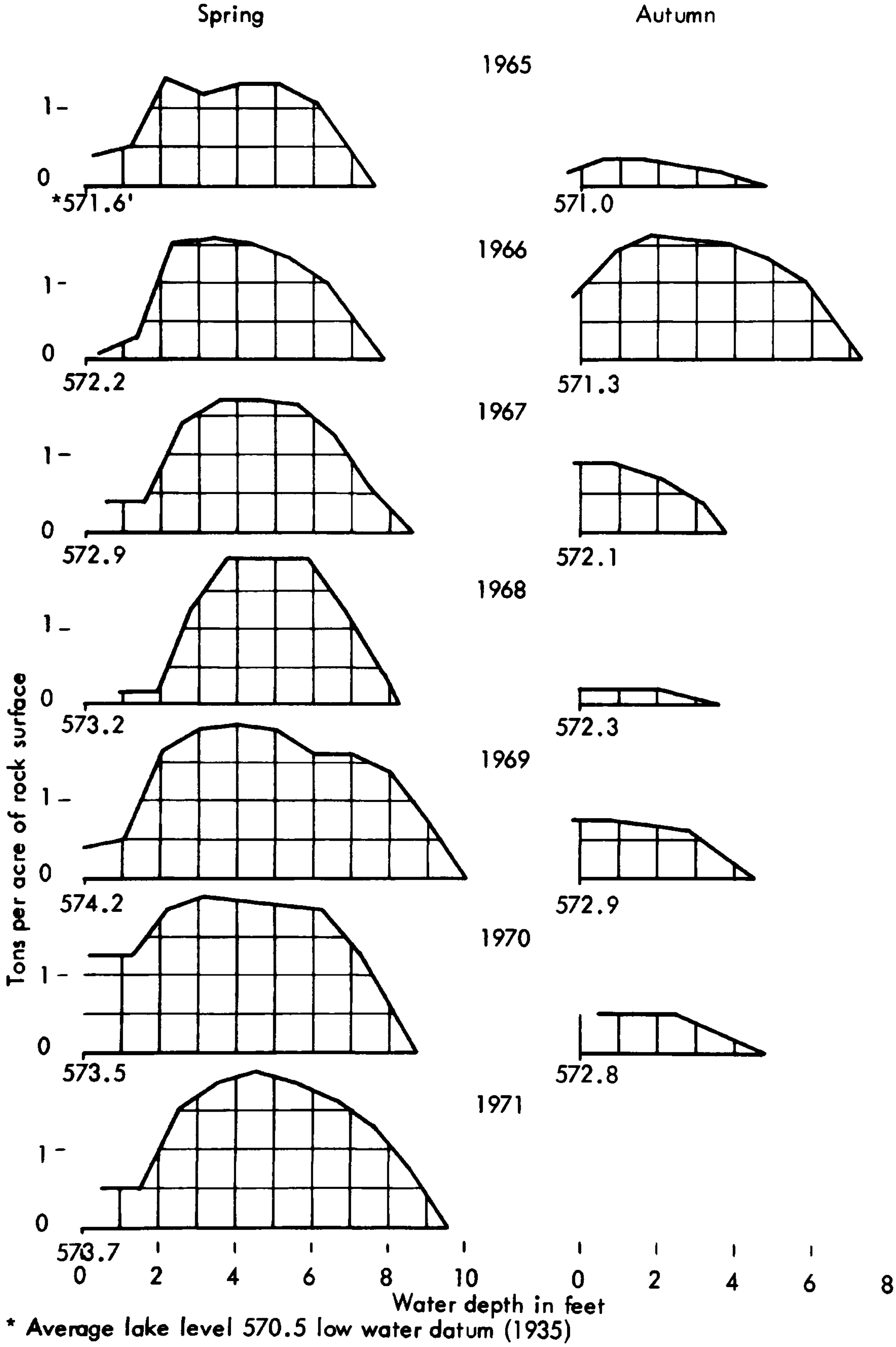


Figure 14. Seasonal Dry Wt. Production of Cladophora at Village Intake.

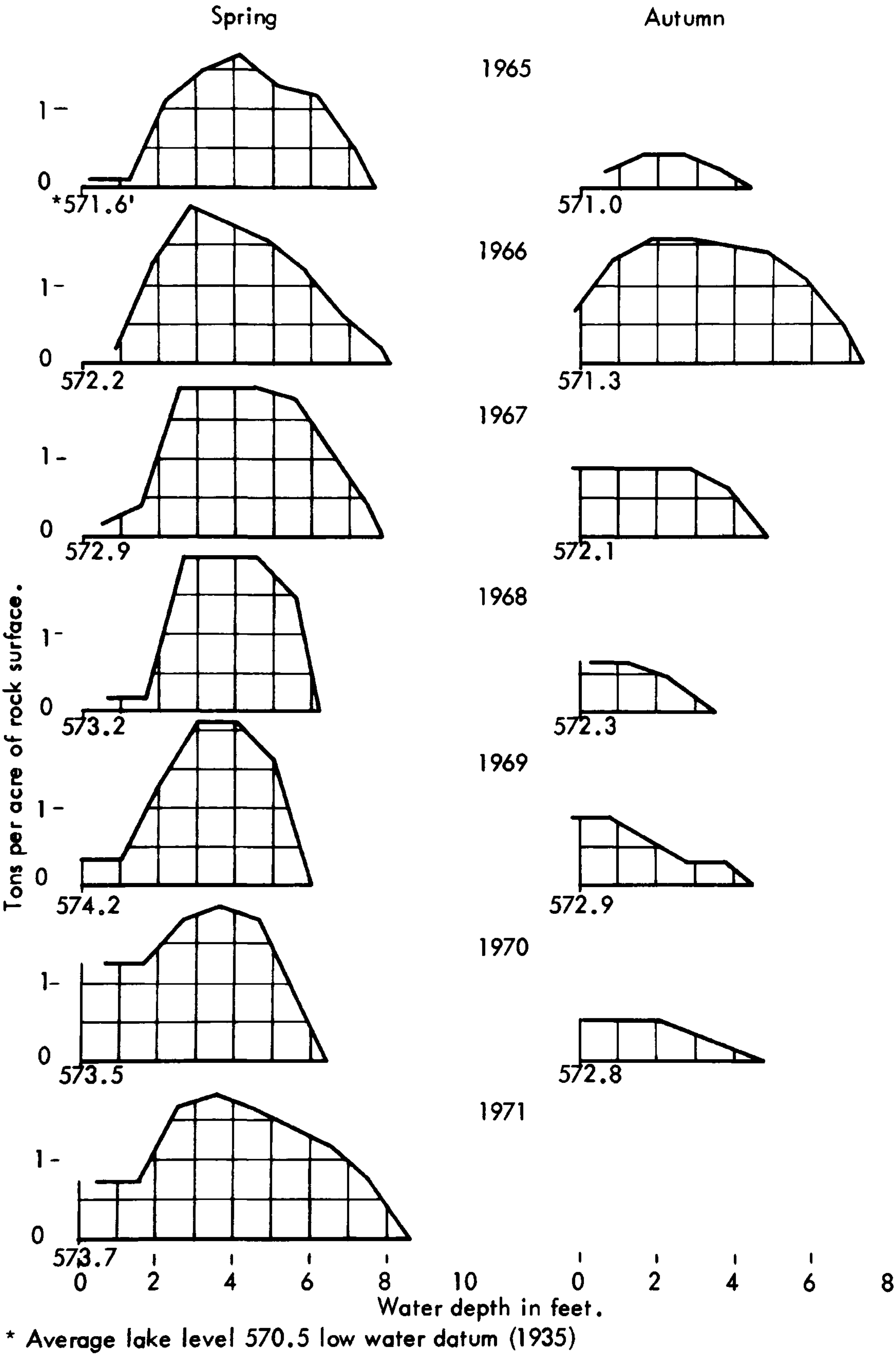


TABLE 3. 27 Selected Cladophora Samples

Ident.	Station	Substrate Rock	Date	Elevation	Coverage sample	Coverage area	Length low	Length average	Length high	Lbs. Dry Weight/sq. ft. Rock Surface	Color basal	Color apical
17	Village Intake N	shelving	6/23	571.6	100	5		6		.0272	6GY5/8	4GY6/10
21	Miller House	shelving	6/25	569.7	100	90		5		.0235	5GY7/10	3Y7/4
24	Gilbraltar E	rubble	6/28	569.7	100	100	3		9	.0168	5GY4/8	2Y4/4
25	Hatchery Intake N	shelving	6/29	569.8	100	100	3	5-1/2	8	.0246	5GY6/8	10Y8/4
30	Middle Bass N	rubble	7/5	569.5	100	70			7	.0130	brown	
34	Middle Sister Twr	rubble	7/7	569.8	100	100			18	.0236	4GY6/8	3GY7/10
36	Catawba Cliffs	rubble	7/7	569.8	100	100			10	.0229	5GY5/8	4GY7/10
37	Catawba Scott Point	rubble	7/7	570.1	100	70			7	.0127	5GY5/8	5Y5/4
45	Kelley's E	shelving	7/12	568.6	100	98		8	16	.0306	6GY5/9	7Y6/8
46	Kelley's Beach	rubble	7/12	565.3	100	40		4	7	.0112	6GY5/10	2Y4/6
50B	Hatchery Intake N	bluff	7/14	571.6	100	50	1	4	8	.0132	5GY5/9	5GY5/9
50S	Hatchery Intake N	shelving	7/14	571.6	100	50	2	5	10	.0204	4GY6/8	3GY8/10
52	Buckeye Point	rubble	7/15	568.3	100	90	3	5	8	.0206	4GY6/8	3Y5/5
53	North Bass Fox's	rubble	7/16	571.6	100	50	1	4	6	.0142	5GY7/10	5GY7/10
533	North Bass Fox's	rubble	7/16	569.0	85	85	4	6	8	.0131	5GY6/8	5GY6/8
55	Honey Point	rubble	7/16	571.6	100	70	4	6	8	.0250	4GY5/8	4Y7/4
56	Lighthouse Point	bluff	7/17	571.7	100	20	2	4	6	.0131	4GY7/10	5Y5/5
58	Pelee Mill Point	shelving	7/19	568.5	100	-	5	7-1/2	12	.0113	6GY5/10	3Y7/4
603	Hatchery Intake N	shelving	7/22	569.0	100	20	4	5	8	.0161	3GY5/6	3Y5/4
60S	Hatchery Intake N	rubble	7/22	567.2	100	90	1	2	5	.0055	3Y3/2	3Y5/4
61	Village Intake N	rubble	7/22	568.7	100	80		-		.0198	6GY5/8	6Y6/6
77A	Village Intake N	shelving	7/29	571.6	100	50	1	5	10	.0261	3Y9/3	3Y9/3
77	Village Intake N	shelving	7/29	571.8	100	50	6	16	22	.0881	6GY7/10	6GY5/8
773	Village Intake N	rubble	7/29	568.6	85	85		-		.0188	2GY6/6	2GY6/6
79	Hatchery Intake N	shelving	8/5	571.3	100	100	4	6	7	.0239	10R5/6	
81	Village Intake N	rubble	8/10	569.5	-	-		5		.0185	4GY7/10	4GY4/4
923	Hatchery Intake N	shelving	9/30	568.9	100	100	2		6	.0096	dark green	

TABLE 3. 27 Selected Cladophora Samples (continued)

Ident.	Remarks	Ash Samples % Dry Wt.	Ash Samples Color	Count per μgm Dry Wt. Rhoicosphenia	Cocconeis	Cymbella	% SiO_2 Dry Wt.
17	epiphytes bunched at branching points	30.6	1Y8/3	2.6	.2	.2	0.04
21	old filaments heavy with Gongrosira, epiphytes and floc	51.7	1Y6/3	2.0	1.3	.2	0.05
24		37.1	10YR8/6	2.5	16.8	.6	0.28
25	Gongrosira	53.1	10YR7/5	4.0	3.2	.2	0.10
30	Phormidium	58.2	8YR7/5	8.6	15.6	.2	0.34
34	light Phormidium, 1% sporangia	22.6	10YR8/6	15.1	3.1	.1	0.26
36	light Phormidium and protozoa, 15% sporangia	24.2	10YR8/4	13.2	2.3	.1	0.22
37	Phormidium, protozoa, 5% sporangia	37.4	8YR7/5	13.9	1.8	.2	0.22
45	Gongrosira, protoplasm at tip of curved branches	35.3	2Y5/2	17.0	5.6	.4	0.32
46	Phormidium	44.1	8YR8/6	31.8	1.6	.1	0.47
50B	somewhat slippery	18.9	2Y8/2	2.9	2.8	.1	0.08
50S	wooly, 10% sporangia	22.1	1Y6/2	2.2	1.8	.1	0.06
52	Phormidium	51.0	10YR8/4	2.7	2.7	< .1	0.08
53		20.0	1Y8/2	.7	1.1	< .1	0.02
533	Phormidium, floc.	34.8	8YR7/6	18.3	.2	.2	0.26
55	Phormidium, protozoa, heavy floc.	31.9	8YR7/5	5.7	.7	0	0.09
56	Phormidium, Stigeoclonium, 5% sporangia	18.1	2Y6/2	4.5	.6	< .1	0.07
58	Gongrosira, Phormidium, protozoa, bent	38.8	1Y8/3	15.0	4.9	.3	0.28
603	protozoa, heavy Phormidium, 1/16" new growth	41.2	8YR7/7	3.1	20.8	0	0.34
60S	protozoa, heavy Phormidium, 1/8" new, floc, knobby	55.1	8YR7/7	9.1	10.8	.2	0.28
61	protozoa, heavy Phormidium, 70% sporangia	40.3	1Y8/6	9.8	4.9	0	0.21
77A	Phormidium, dead.	21.5	1Y8/5	.2	.1	0	0.01
77	Phormidium, some sporangia, bulbous cells	22.2	1Y7/5	.3	5.1	0	0.08
773	heavy Phormidium	26.0	1Y8/5	1.7	2.4	0	0.06
79	purple Phormidium sp., Stigeoclonium	27.3	1Y8/6	5.0	1.9	0	0.10
81	Phormidium	37.2	9YR7/5	5.6	.4	< .1	0.08
923	dark, somewhat silky	27.4	8YR7/6	.8	.7	< .1	0.02

TABLE 3. 27 Selected Cladophora Samples (continued)

Ident.	Element fractions of Dried Material %						ppm									
	Ca	K	Si	Mg	P	Na	Fe	Al	Mn	Sr	B	Ba	Zn	Mo	Cu	Co
17	5.51	3.43	1.58	0.26	0.25	0.08	1914	746	139	232	78	39	37	28.07	12	3.19
21	7.06	1.48	2.06	0.40	0.20	0.08	2149	764	297	287	80	54	70	> 30.	15	5.25
24	5.41	2.34	1.78	0.28	0.31	0.07	2085	760	302	160	80	39	33	> 30.	12	2.95
25	6.17	1.69	2.00	0.33	0.35	0.06	2177	764	560	144	80	49	36	> 30.	10	3.29
30	6.49	0.91	1.99	0.43	0.31	0.05	2182	765	459	148	78	52	83	> 30.	18	3.89
34	1.70	3.09	0.91	0.33	0.51	0.07	1761	721	211	50	80	22	49	11.07	21	.79
36	2.79	3.14	0.85	0.25	0.44	0.06	1679	721	181	110	79	24	31	8.73	20	1.10
37	5.28	1.83	1.72	0.30	0.36	0.07	2176	762	360	122	80	43	48	> 30.	13	2.90
45	6.64	2.33	1.35	0.22	0.22	0.08	1721	731	199	268	79	42	32	13.18	12	3.67
46	4.75	1.28	2.15	0.32	0.38	0.06	2156	766	411	93	80	47	63	> 30.	17	2.74
50B	2.30	3.78	0.45	0.29	0.37	0.08	1236	529	215	111	78	17	30	1.61	25	.61
50S	3.31	3.36	0.77	0.27	0.22	0.07	1371	650	190	111	78	23	27	3.82	14	1.58
52	7.10	1.96	1.75	0.45	0.37	0.08	2090	756	364	296	80	54	91	> 30.	19	7.64
53	2.88	4.01	0.72	0.25	0.39	0.07	1404	612	150	94	79	19	36	3.03	15	1.35
533	4.52	1.49	1.61	0.34	0.40	0.06	2184	765	373	108	80	45	47	> 30.	11	1.76
55	5.01	2.11	1.29	0.27	0.40	0.06	2125	758	264	132	80	38	33	> 30.	11	2.83
56	1.85	2.70	0.37	0.26	0.35	0.07	1247	594	192	109	80	16	26	1.97	8	.53
58	5.17	2.71	1.53	0.25	0.22	0.06	2054	742	185	128	78	33	40	23.83	20	2.99
603	4.38	1.46	1.76	0.30	0.36	0.06	2180	765	445	93	79	43	40	> 30.	17	1.28
60S	4.73	0.90	1.67	0.40	0.34	0.06	2190	766	563	70	74	51	58	> 30.	15	2.13
61	6.42	1.71	2.06	0.39	0.33	0.06	2166	764	523	173	79	49	40	> 30.	12	3.66
77A	4.41	0.23	0.67	0.28	0.16	0.05	1717	687	188	127	77	31	29	5.34	11	2.44
77	3.13	2.38	1.25	0.27	0.33	0.07	1920	733	320	88	78	29	24	13.18	16	1.17
773	3.68	1.46	1.52	0.32	0.31	0.06	2141	750	344	88	79	34	35	26.90	20	1.19
79	4.03	1.82	0.68	0.29	0.35	0.06	2067	721	200	108	79	28	34	9.63	19	1.56
81	5.62	1.21	0.97	0.34	0.37	0.06	2170	753	410	141	80	42	38	> 30.	13	2.99
923	3.10	2.78	0.99	0.51	0.42	0.08	2169	757	228	65	80	32	47	> 30.	20	1.17
average, tons	4.57	2.13	1.35	0.32	0.33	0.066	1942	726	306	135	79	37	43	> 21.	15	2.47
1966	494	230	146	35	36	7	21.00	7.85	3.31	1.46	.85	.40	.46	> .23	.16	.03

TABLE 4. Total Map Acres at One Foot Elevation Intervals.

Elevation Mean Sea Level		South Bass Island* E Shore	W Shore	Put-in-Bay	Total	Middle Bass	North Bass
	575-						
(568.6IGLD'55)	570.5-	24	21	2	47	99	64
	564.5-	379	89	83	551	460	319
	558.5-	403	83	35	521	339	390
	575-	6	6	1	13	44	33
		5	5	0	10	17	12
	573-	4	3	0	7	12	7
		5	5	1	11	15	7
	571-	9	5	2	16	25	12
		17	5	4	26	40	25
	569-	32	8	8	48	63	47
		64	13	15	92	95	59
	567-	91	21	20	132	107	69
		111	26	24	161	97	74
	565-	112	25	19	156	85	74
		81	19	11	111	72	72
	563-	68	16	6	90	62	67
		61	13	4	78	54	64
	561-	57	11	3	71	47	62
		54	10	2	66	42	60
	559-	51	9	2	62	39	59
		49	8	2	59	37	57
	557-						55
	555-						
	553-						

*South Bass Island littoral zone includes that of Starve, Ballast, and Gibraltar Islands; Middle Bass - Sugar

TABLE 4. Total Map Acres at One Foot Elevation Intervals (continued).

Elevation Mean Sea Level		Kelley's	West Reef	Gull Shoal	Kelley's Shoal	Total	Rock Surface / Map Area
	575-						
(568.6IGLD'55)	570.5-	72	0	0	0	282	
	564.5-	692	22	84	45	2173	
	558.5-	657	257	153	138	2455	
	575-	32				122	1.16
		12				51	1.25
	573-	7				33	1.33
		12				45	1.26
	571-	20		2		75	1.20
		35		3		129	1.15
	569-	63		6		227	1.11
		112		11	2	371	1.08
	567-	184		21	9	522	1.06
		198		28	22	580	1.05
	565-	157	42	29	24	567	1.07
		114	44	28	24	465	1.11
	563-	109	45	27	24	424	1.14
		107	44	25	23	395	1.18
	561-	104	43	24	22	373	1.20
		103	41	22	22	357	1.21
	559-	100	40	22	22	344	1.22
		98	39	20	22	332	1.23
	557-	95	37	19	22		1.23
		93	36	18	21		1.24
	555-			17	20		1.25
					19		1.25
	553-						

TABLE 5. Monthly Dry Weight Production of Cladophora at South Bass Island in Tons: April - December

1965 - Attached

Area	A	M	J	J	A	S	O	N	D	Total
West Shore	3	35	45	4	1	< 1	4	4	0	96
East Shore	7	266	291	13	2	< 1	5	9	0	593
Total	10	301	336	17	3	0	9	13	0	689

1966 - Attached

Area	A	M	J	J	A	S	O	N	D	Total
West Shore	4	31	43	7	15	5	49	66	0	220
East Shore	10	227	212	21	2	< 1	236	313	0	1021
Total	14	258	255	28	17	5	285	379	0	1241

1966 - Detached

Area	A	M	J	J	A	S	O	N	D	Total
West Shore	2	0	64	19	2	18	< 1	0	115	220
East Shore	4	0	399	67	2	0	< 1	0	549	1021
Total	6	0	463	86	4	18	0	0	664	1241

TABLE 6. Cladophora Production at One Foot Elevation Intervals in Tons: 1966

Elevation	South Bass Island E Shore	South Bass Island W Shore	South Bass Island Total	Middle Bass	North Bass	Kelley's	West Reef	Gull Shoal	Kelley's Shoal	Total
573-	4	3	7	12	8	9				36
	5	5	10	25	8	16				59
571-	24	15	39	74	39	73		7		232
	66	19	85	158	108	171		14		536
569-	114	28	142	235	196	297		29		899
	209	41	250	322	235	511		51	10	1379
567-	268	55	323	386	251	813		95	44	1912
	228	39	267	175	235	804		126	106	1713
565-	103	15	118	81	148	593	173	131	118	1362
					77	284	172	121	122	776
563-						144	155	105	124	528
								62	113	175
561-								32	97	129
									61	61
559-									32	32
557-										
Total	1021	220	1241	1468	1305	3715	500	773	827	9829

Figure 15. Range Lines of detached Cladophora on the bottom of Lake Erie in the Bass Island Region.

Table 7. Nutrient concentrations near the Hatchery Intake, South Bass Island.

	10w	average	high
Total phosphate	.04	.13	.29
Total soluble phosphate	.01	.10	.24
Nitrate nitrogen	.01	.22	.66
Ammonium nitrogen	.05	.14	.39
Organic nitrogen	.30	.67	1.30

Eleven water samples were taken from 18 June to 8 August, 1965 and thirteen samples from 23 March to 26 May and 23 August to 28 September, 1966. Samples represent a wide range of weather and lake conditions. The chemical analyses as summarized above are in ppm.

TABLE 8. Effect of the amount of Cladophora on 0_2 output.

Live wt.	test time/min.		μ mol 0_2/g. Cladophora/hr.		
g.	AM	PM	AM	PM	Ave.
.95	33	24	127	165	146
.425	44	33	144	196	170
.115	52	47	196	196	196
.012	60	71	231	293	262
lake water	64	86	1.3	0.3	0.8

7 Aug. 1969; 10:00 - 11:04, 3:07 - 4:33; haze; 24.5^0 C

TABLE 9. Effect of stirring on CO_2 intake.

Cladophora live wt. g.	bottle still	μ mol CO_2/g./hr. stirred
.5	118	153
.5 dark	-9.5	-12

28 July 1966; 88 - 119 min.; 24^0 C. Bottle inverted by hand for stirring.

TABLE 10. Effects of aging in bottled water and stirring on O_2 output.

water	live wt. g.	19 Aug.	20 Aug.	21 Aug.	25 Aug.
			μ mol O_2/g./hr.		
distilled	.18	65	72	183 - wave stir	0
"	.22	83	68	173 - " "	2
"	.29	74	68	104 - on ground	0
", dark	.62	-12	-11	-10 - " "	-8
lake	.19	156	180	389 - wave stir	7
"	.31	148	129	172 - on ground	2
"	.32	134	133	231 - wave stir	103
"	.35	142	132	148 - on ground	1
", dark	.44	-10	-10	-27 - wave stir	-26

19 Aug. 1969, 10:12 - 12:33, 118 - 140 min.; clear; 25.3^0 C.
20 " " , 9:31 - 11:43, 106 - 131 min.; clear; 23.5^0 C.
21 " " , 11:33 - 1:56, 117 - 142 min.; clear; 25.0 - 26.5^0 C., wave stirred; 25.0 - 36.0^0 C on ground.
25 " " , 10:21 - 1:25, 162 - 174 min.; clear; 25.0^0 C.

TABLE 11. Effect of aging in bottled water on O_2 output.

live wt. g.	14 Aug. fresh	14 Aug. overnight	15 Aug. overnight	15 Aug. 2nd night
		μ mol O_2/g. <u>Cladophora</u>/hr.		
.16	110		91	
.31	104		84	
.85	78		80	
.28		87		73
.75		78		78
.78		75		61
.86		74		76
1.71 dark	-11		-17	
1.38 dark		-11		-17

14 Aug. 1969; 9:51 - 11:41, 89 - 99 min.; clear; 23.5^0 C.
15 " " ; 9:53 - 11:42, 89 - 98 min.; clear; 24.0^0 C.

TABLE 12. Effect of temperature on O_2 output under natural light.

Cladophora live wt. g.	27 Aug. Temperature °C	27 Aug. O_2 μmol/g./hr.	28 Aug. Temperature °C	28 Aug. O_2 μ mol/g./hr.
1.22	36	-16	33 - 35	-14
.71	36	-9	33 - 35	1
1.04	36	-2	24	1
.68	24 - 31	19	33 - 35	46
1.28			24	51
1.43			14 - 20	46
1.48	19	16	24	63
1.23	19	-6	14 - 20	-2
1.20	19	17	14 - 20	50

27 Aug. 1969; 4:25 - 6:08, 85 - 103 min.; clear; in bath on ground.
28 Aug. 1969; 10:14 - 12:12, 95 - 114 min.; clear; in bath on ground.

TABLE 13. Effect of temperature on O_2 output under artificial light.

Cladophora live wt. g.	21 Oct.				22 Oct.		
	7.7^{0}C	14.8^{0}C	22.7^{0}C	27.0^{0}C	21.1^{0}C	16.3^{0}C	11.2^{0}C
	μ mol. O_2/g./hr.						
1.09	-8.3 dark	32.2	-17.7 dark	40.2	-15.4 dark	34.8	-4.5 dark
1.32	-6.0 dark	25.8	-12.4 dark	39.3	-14.4 dark	34.1	-5.0 dark
0.92	17.8	-7.6 dark	16.3	-17.4 dark	49.6	-12.5 dark	33.4
1.33	17.6	-8.8 dark	15.0	-11.8 dark	41.6	-11.7 dark	29.1

21 Oct. 1969; 108 - 111 min., 102 - 111 min., 100 - 107 min.
22 " " ; 78 - 79 min., 104 - 106 min., 97 - 99 min.
Bottles placed in baths in darkroom, 9 inches below a 60 W. incandescent light bulb.

TABLE 14. Effect of temperature shock preconditioning on O_2 output.

Cladophora live wt. g.	precondition °C	O_2 μ mol./g./hr.
1.38	34 - 35° for 10 min.	33
.91	none	50
.72	34 - 35° for 5 min.	56
.71	none	60
.69	5 - 7° for 3 min.	53
.57	34 - 35° for 2 min.	75
.57	5 - 7° for 10 min.	75
1.84 dark	34 - 35° for 6 min.	-6
1.04 dark	5 - 7° for 6 min.	-6

29 Aug. 1969; 10:43 - 1:28, 139 - 149 min.; clear; 23.5 - 24.0° C

TABLE 15. Effect of distilled water on O_2 output.

water	live wt. g.	*Cladophora* 10 Aug. μ mol./g./hr.	*Cladophora* 11 Aug. μ mol./g./hr.
lake	.42	94	70
distilled	.26	113	125
distilled, dark	.29	-17	-11

10 Aug. 1969; 4:13 - 4:51, 26 - 38 min.; 25.0°C.
11 Aug. 1969; 9:47 - 11:31, 92 - 104 min.; 23.5°C.

TABLE 16. Effect of dissolved chemicals on O_2 output.

water	pH	live wt. g.	*Cladophora* μ mol/g./hr.
lake	9.2 - 9.6	.31	82
34% lake, 66% 0.5% sol'n NaCl	8.6 - 9.4	.38	44
34% lake, 66% 0.5% sol'n $NaHCO_3$	8.2 - 8.8	.19	79
34% lake, 66% 0.5% sol'n $C_6H_{12}O_6$	9.2 - 9.7	.46	23
34% lake, 66% distilled water	8.5 - 9.2	.05	180
lake, dark bottle	9.2	.26	-13

1 Aug. 1969; 3:35 - 5:57, 108 - 130 min.; cloudy; 24.6°C.

TABLE 17. Effect of natural waters on O_2 output of various algae. (A)

water	Fishery Bay *Cladophora* live wt. g.	Fishery Bay *Cladophora* 11 Aug. μ mol/g./hr.	Fishery Bay *Cladophora* 12 Aug. μ mol/g./hr.	West Shore *Cladophora* live wt. g.	West Shore *Cladophora* 11 Aug. μ mol/g./hr.	West Shore *Cladophora* 12 Aug. μ mol/g./hr.
Fishery Bay	.22	123	149	.52	71	92
Fishery Bay	.22	118	192	1.10	-6, dark	0, dark
West Shore	.33	99	141	.44	78	112

11 Aug. 1969; 2:51 - 5:44, 157 - 173 min.; 25.7°C.
12 Aug. 1969; 9:05 - 10:32, 68 - 87 min.; 23.9°C.

TABLE 17. Continued. (B)

water	east shore *Cladophora* live wt. g.	east shore *Cladophora* μ mol/g./hr.	west shore *Cladophora* live wt. g.	west shore *Cladophora* μ mol/g./hr.
east shore	.49	210	.22	360
east shore	.53	210		
west shore	.39	250	.23	350

7 Aug. 1969; 1:58 - 2:52, 50 min.; haze; 25.0°C.

TABLE 17. Continued. (C)

Water	*Rhizoclonium g.	*Rhizoclonium μ mol O_2/g./hr.	*Cladophora* - S. B. g.	*Cladophora* - S. B. μ mol O_2/g./hr.	*Cladophora* - L. g.	*Cladophora* - L. μ mol O_2/g./hr.	Blank μ mol O_2/g./hr.
				(1)			
Pond	.03	1370	.10	400	.09	285	
Bay	.03	-160	.09	398	.18	-16, dark	
				(2)			
Bay					.15	89	1
Lake	.04		.05		.05	164	
					.18	-20, dark	

5 Aug. 1969; (1) 3:35 - 5:08, 84 - 93 min., (2) 5:32 - 7:48. 126 - 142 min.; clear; 26.8°C.; pH pond, 8.7 - 9.5, bay 9.3 - 9.7, lake 8.9 - 9.7.
*Rhizoclonium collected in pond at the Maples Experiment Station.
Cladophora - S.B. collected from Sandusky Bay at the Maples Experiment Station.
Cladophora - L. collected at west shore station.

TABLE 18. Effect of light on O_2 output of various algae.

depth ft.	ave. light μ amp	Cladophora dry wt. g.	Cladophora μ mol O_2 /g./hr.	Bangia dry wt. g.	Bangia μmol O_2 /g./hr.	lake water μ mol O_2/bottle/hr.
0.5	1510	.025	470	.025	440	3
7.5	92	.04	210	.08	220	
	dark bottle	.06	-42			

15 May, 1969; 4:13 - 5:32, 65 - 67 min.; cirrus clouds; 14.2 - 13.8^{0}C

TABLE 19. Effect of light on O_2 output and CO_2 intake of various algae. (A)

live wt.	alga	depth ft.	14 Oct. average light μ amp	14 Oct. O_2 μ mol/g./hr.	14 Oct. CO_2 μ mol/g./hr.	15 Oct. average light μ amp	15 Oct. O_2 μ mol/g./hr.	15 Oct. CO_2 μ mol/g./hr.
		0	2960-1750			2920-1900		
.15	Cladophora	2	1125	238	262	1035	257	234
.29	Cladophora	2	1125		202	1035		165
.17	Plectonema	2	1125	195	200	1035	200	186
	lake water	2	1125	7	24	1035	8	24
.19	Cladophora	10	89	68	76	100	87	80
.37	Cladophora	10	89	67	50	100	80	56
.15	Plectonema	10	89	127	119	100	129	116
	lake water	10	89	9	10	100	7	12
.41	Cladophora	17	8.0	8	18	11.0	27	27
.73	Cladophora	17	8.0	-7	10	11.0	-4	9
.11	Plectonema	17	8.0	5	69	11.0	17	74
.20	Plectonema	17	8.0	18	39	11.0	30	42

14 Oct. 1968; 1:15 - 4:35, 85 - 200 min.; clear; 16.3 - 15.0°C.; pH 7.93 - 8.46, 9.38.
15 Oct. 1968; 1:10 - 4:15, 55 - 155 min.; clear; 16.6 - 15.1°C.; pH 7.97 - 8.26, 8.92.

TABLE 19. Continued. (B)

live wt.	dry wt.	alga	depth ft.	21 Oct. average light μ amp	21 Oct. O_2 μ mol/g./hr.	21 Oct. CO_2 μ mol/g./hr.	23 Oct. average light μ amp	23 Oct. O_2 μ mol/g./hr.	23 Oct. CO_2 μ mol/g./hr.
		*	0	2920-1810			2330-1720		
.23	.044	P	2	1465	77	99	1120	72	95
.17	.029	C-w	2	1465	172	178	1120	145	154
.12	.016	C-e	2	1465	279	284	1120	226	234
	lake water		2	1465	8	17	1120	1	8
.21	.040	P	10	130	46	54	57	20	31
.57	.085	C-w	10	130	27	37	57	21	16
.62	.081	C-e	10	130	41	41	57	27	26
	lake water		10	130	3	9	57	-1	4
.38	.082	P	17	11	1	19	2	1	7
.68	.097	C-w	17	11	-4	6	2	-1	0
1.03	.130	C-e	17	11	-9	0	2	-6	-2
	lake water		17	11	0	2	2	-2	0

21 Oct. 1968; 1:57 - 4:59, 33 - 156 min.; 15.7 - 15.5°C; pH 8.12 - 8.12, 8.90.
23 Oct. 1968; 11:44 - 3:10, 74 - 168 min.; 14.5 - 14.2°C; pH 8.19 - 8.03, 8.77.

*C-w -- Cladophora from west shore station.
*C-e -- Cladophora from east shore station.
*P -- Plectonema (July stock).

TABLE 20. Effect of light on O_2 output and CO_2 intake.

live wt. g.	depth ft.	average light μ amp	*Cladophora* O_2 μ mol/g./hr.	*Cladophora* CO_2 μ mol/g./hr.	lake water O_2 μ mol/g./hr.	lake water CO_2 μ mol/g./hr.
.217	0.1	1770	48	66	5	8
.252	1.0	940	24	45	-2	6
.210	3.4	120	-5	14	-2	0

13 Nov. 1968; 11:57 - 5:08, 250 - 285 min.; 7.2 - 8.6^{0}C; pH 8.50 - 8.49, 9.52.

Appendix C - Bibliography of Cladophora

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